Abstract ID: 94375

Title: SuperMAG geomagnetic indices: Do more stations provide better monitoring of the M-I current system?

Presenter/First Author: Jesper W Gjerloev, Johns Hopkins University - Applied Physics Laboratory, Laurel, MD

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Presenter/First Author Student?: No

Published Material: 0%

Abstract Body: Over the last few years a wave of new indices have been proposed and released through the SuperMAG initiative. The basic assumption behind these indices is that the more stations used to derive the indices the better the current systems are monitored. This supposedly includes improved timing, intensity and location. Examples are the ring current indices (IAGA SYM-H use six station vs. SuperMAG SMR using ~100 stations) and auroral electrojet indices (IAGA AE use 12 stations vs. SuperMAG SME using ~110 stations).

The purpose of the various magnetic indices is to provide information of the currents in question. The pitfalls, however, are many: 1) do the indices have appropriate temporal resolution? 2) are they derived from a network of stations with sufficient spatial coverage? 3) is it reasonable to assume that a given level of an index implies a certain 2D current distribution? 4) to what extend do the indices actually monitor the current system in mind? To address some of these problems SuperMAG indices with local time information has been published (e.g. SME 24 local time indices and SMR 4 local time indices).

The basic purpose of the various indices is to monitor the M-I current system. We discuss to what extend the IAGA and SuperMAG indices actually fulfill this objective.

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Abstract ID: 94413

Title: Ring Currents in Planetary Magnetospheres

Presenter/First Author: Nick Sergis, National and Kapodistrian University of Athens, Athens,

Presenter/First Author Email: nsergis@phys.uoa.gr

Presenter/First Author Student?: No

Published Material: 75%

Abstract Body: Nearly a century ago, Schmidt [1917] and Chapman [1919] first proposed that the magnetic field depression during magnetic storms was caused by electrical currents flowing near the Earth, fed by charged particles of solar origin. In the early 1930s, Chapman and Ferraro suggested that a solar charged particle flow (later established by Parker as the “solar wind”) could leak into the magnetosphere and drift around the Earth, creating an electric current whose field would oppose the intrinsic terrestrial field. Today, we know well how the interaction of planets with the solar wind produces a variety of current systems, usually classified as ionospheric currents, magnetospheric boundary currents, magnetotail currents, and currents flowing inside the magnetosphere, such as the ring current, the plasma sheet current and the field-aligned currents. The inhomogeneity (gradient and curvature) of the planetary magnetic field produces an azimuthal drift of charged particles with ions and electrons moving in opposite directions. The combined gradient and curvature drifts, result in a net motion of current charges, a planetary “ring” current. Its average structure and intensity are functions of the plasma population that carry the current and the particular characteristics of each system. In rapidly rotating magnetospheres, such as those of Jupiter and Saturn, the ring current is strongly modified by the inertial forces that also tend to form a disc-shaped outer magnetosphere. If the magnetospheric plasma beta is close to 1, the azimuthal current produces magnetic perturbations that can significantly modify the planetary magnetic field, an effect that has been well observed in Earth, Jupiter and Saturn, but is relatively small (weak ringcurrent) for Uranus and Neptune, although these two planets also have radiation belts. In this talk, we focus on the description, particular characteristics (plasma sources, rotational and plasma beta regime, anisotropies) and interplanetary variability of the magnetospheric ring currents, based on in-situ and remote (Energetic Neutral Atoms) observations, where available. We also examine the relative strength of different ring current contributors and we attempt a qualitative comparison between different magnetospheric
Abstract ID: 94470

Title: Terrestrial Ring Current: a Review of Some Cluster Results Based on the Curlometer Technique

Presenter/First Author: Iannis S Dandouras, IRAP, Toulouse,

Presenter/First Author Email: Iannis.Dandouras@irap.omp.eu

Presenter/First Author Student?: No

Co-authors: Sandrine Grimald, ONERA Toulouse, Toulouse Cedex 04, France

Published Material: 50% at the "Geospace revisited: a Cluster/MAARBLE/VAP Conference", Rhodes, Greece, Sep. 2014

Abstract Body: The inner magnetospheres electric currents configuration and mapping is one of the key elements for understanding current loop closure inside the entire magnetosphere. The ring current is toroidal-shaped and flows in the near-Earth region, where the magnetic field is dipole-like. This current system is driven by the pressure gradients, and it is formed by the drift of the charged particles that are injected from the magnetotail towards the Earth during the magnetospheric storms and substorms. A method for directly computing current is the multi-spacecraft curlometer technique, which is based on Maxwell-Amperes law application. This requires the use of four point simultaneous magnetic field measurements. The FGM experiment on board the four Cluster spacecraft allowed for the first time an instantaneous calculation of the magnetic field gradients and thus a measurement of the local current density. This technique requires however a careful analysis concerning all the factors that can affect the accuracy of the current density calculation. The CIS experiment, on board these spacecraft, provides the ion distribution functions of the current carriers within its energy range. Earlier and more recent results, based on Cluster data acquired during passes in the ring current region at different perigee altitudes, will be reviewed in the light of recent progress on the accuracy of the method.

Abstract ID: 94486

Title: Variability of Jupiter’s Magnetospheric Current Sheet Associated with Time-Dependent Mass-Loading, Transport and Chemistry in the Io Plasma Porus
Jupiter's magnetospheric current sheet is generated by stresses imposed by rapid planetary rotation and hot plasma in the plasma sheet. The current carried in this current sheet is known to be variable on time-scales of months but the origin of this variability is not well-understood. Volcanic activity on the moon Io is also known to be variable and feeds plasma into the plasma sheet via the Io plasma torus. In this paper we investigate how this variability in the plasma source affects the current sheet.

We solve the time-dependent equations for diffusive radial transport coupled with a neutral-plasma chemistry model, thus allowing for time-dependent plasma sources and the motion of radial structures produced by such time-dependence. These time-dependent solutions are coupled to a semi-empirical Euler potential magnetospheric model to calculate time-dependent magnetospheric currents. In this paper we review our understanding of the jovian magnetospheric current sheet, present our modelling methodology, and apply this to understand the observed time-variability in the current sheet.

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Title: The impact of the geocorona dynamics on the ring current formation and decay

Presenter/First Author: Raluca Ilie, University of Michigan Ann Arbor, Ann Arbor, MI

Presenter/First Author Email: rilie@umich.edu

Abstract Body: The geocorona plays an important role in the energy budget of the Earth's inner magnetosphere since charge exchange of energetic ions with exospheric neutrals makes the exosphere act as an energy sink for ring current particles. Long-term ring current decay following a magnetic storm is mainly due to these electron transfer reactions, leading to the formation energetic neutral atoms (ENAs) that leave the ring current system on ballistic trajectories.

The number of ENAs emitted from a given region of space depends on several factors, such as the energy and species of the energetic ion population in that region and the density of the neutral gas with which the ions undergo charge exchange. However, the density and structure of the exosphere are strongly dependent on changes in atmospheric temperature and density as well as charge exchange with the ions of plasmaspheric origin, which depletes the geocorona (by having a neutral removed from the system). Moreover, the radiation pressure exerted by solar far-ultraviolet photons pushes the geocoronal hydrogen away from the Earth in an anti-sunward direction to form a tail of neutral hydrogen.

We assess the influence of geocoronal neutrals on ring current formation and decay by analysis of the predicted ENA emissions using various geocoronal models and simulations from the Hot Electron and Ion Drift Integrator ring current model during storm time. Comparison with TWINS ENA images shows that the location of the peak ENA enhancements is highly dependent on the distribution of geocoronal hydrogen density. We show that the neutral dynamics has a strong influence on the time evolution of the ring current populations as well as on the formation of energetic neutral atoms.

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Title: Ring current modeling: Uncommon Assumptions and Common Misconceptions

Presenter/First Author: Raluca Ilie, University of Michigan Ann Arbor, Ann Arbor, MI

Presenter/First Author Email: rilie@umich.edu

Abstract Body: The geocorona plays an important role in the energy budget of the Earth's inner magnetosphere since charge exchange of energetic ions with exospheric neutrals makes the exosphere act as an energy sink for ring current particles. Long-term ring current decay following a magnetic storm is mainly due to these electron transfer reactions, leading to the formation energetic neutral atoms (ENAs) that leave the ring current system on ballistic trajectories.

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**Abstract Body:** The dynamics of the ring current involve plasma transport, losses, strong coupling between residing plasma and large scale electric and magnetic fields as well as wave-particle interactions. While in-situ measurements of the inner magnetosphere broaden our understanding of the dynamic processes that dominate this region, the energization of the system remains a difficult issue to examine using observations alone. Consequently, numerical simulations provide an excellent complementary method for investigating the large-scale coupling of the solar wind-ionosphere-magnetosphere system.

Despite many years of ring current modeling, which led to qualitative and quantitative progress in the understanding of such complex processes, predicting the creation and demise of the ring current still requires several sets of assumptions, ranging from boundary conditions, composition knowledge to physical limitations of equations sets. Knowledge of these caveats is required in order to avoid misinterpretations of the results.

We present here the outcome from a first ISSI international team meeting, which gathered together experts on this topic to examine these common/known and less common/known facets of ring current modeling. Our overarching goal is to define, classify and systematically assess the validity of the equation set each modeling approach is assuming and to reach an understanding of the common misconceptions in interpreting the results while providing answers to the following questions:

1. What are the common/uncommon assumptions we make and should they be revisited?
2. What do we know so far from kinetic, MHD, particle tracing, empirical modeling?
3. What do model dependent results are teaching us?
4. What data sets do we need in order to improve the theoretical representation of the inner magnetosphere currents?

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**Abstract ID:** 94502

**Title:** Partial to full ring current evolution and energization during geomagnetic storms

**Presenter:** Reinhard H Friedel, New Mexico Consortium, Los Alamos, NM

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**First Author:** Michael Denton, New Mexico Consortium, Los Alamos, NM

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**Abstract Body:** It is generally acknowledged that the ring current develops from medium energy ions and electrons (few keV) in the plasma sheet and that this population is energized during enhanced geomagnetic activity. The source plasma is delivered to the inner magnetosphere during periods of enhanced convection, upon which energization takes place. We present observations of the transition from partial ring current to circular ring current the and energization during geomagnetic storms, both statistically and for particular events. Measurements of the ion composition from the HOPE instruments on Van Allen Probes (O+, H+, He+), and of ions and electrons from the MagEIS instruments, demonstrate a complex evolution of the ring current as geomagnetic storms evolve. Our results confirm the energization of the source population during storms, quantify the energization as a function of L and MLT, and also provide the composition ratios as a function of energy - all essential factors in modeling/predicting ring current development. Further, we attempt to pinpoint both the location in L and MLT and timing of the partial to full ring current transition using the two spacecraft measurements of the Van Allen Probe Mission.
Title: Pressure-Driven Current Systems in the Solar System

Presenter/First Author: Pontus C. Brandt, Johns Hopkins Univ/APL, Laurel, MD

Presenter/First Author Email: pontus.brandt@jhuapl.edu

Abstract Body: The ring current systems of Earth, Saturn and Jupiter are compared. At Earth, the ring current is primarily associated with energetic particle pressure gradients and its morphology and dynamics are governed primarily by the direction of the interplanetary magnetic field (IMF). For southward IMF the ring current is asymmetric (storm "main phase") with a pressure peak that is fixed around the midnight sector, where the bulk of the pressure lies in the approximate range of 10-300 keV protons. Depending on the duration of the southward IMF, O+ may dominate the pressure. The main phase ring current dictates the structure of the inner magnetosphere. For northward IMF, the ring current becomes symmetric around Earth. The asymmetric main-phase pressure distributions drive a 3D current system that couples the magnetosphere and ionosphere, often referred to as the Region-2 current system. At Saturn, the plasma pressure of the energetic protons and O+ in the approximate same (10-300 keV) energy range dominates roughly outside 9 RS as a result of periodic large-scale injections in the midnight sector. Because of the strong corotational electric field at Saturn, the injected energetic particle distributions form a PRC system drifting around the planet, also distorting the magnetic field in a periodic fashion as seen by the relatively slow-moving Cassini spacecraft. At Jupiter, the current systems around the planet form a magnetodisc, whose formation and stability is dependent on the centrifugal forces of the radially outward diffusing low-energy plasma. However, the structure of the magnetodisc is likely also formed as a result of pressure anisotropies in the energetic particles. The force balance of the three systems is contrasted against each other and their roles in the magnetic structure and ionospheric coupling of the inner magnetosphere are discussed.

Abstract ID: 94526

Title: Solar Activity and the Terrestrial Ring Current

Presenter/First Author: Walter Gonzalez, INPE National Institute for Space Research, Sao Jose dos Campos,

Presenter/First Author Email: walter.gonzalez@inpe.br

Abstract Body: We will discuss about the evolution and intensity of the Terrestrial Ring Current (TRC) in association with the variability of solar activity during the solar cycle phases. This will involve the response of the TRC to solar active regions, as main sources for ICMEs, and to coronal holes as sources of high speed streams, and to the combination of both. Also, we will try to include in our discussion the complex issues regarding the response of the TRC to extreme solar activity and the meaning of the Dst index as a monitor of “TRC intensification” during large magnetotail current intensifications.
CURRENT SHEETS

Abstract ID: 94265
Title: Planetary Current Sheets
Presenter/First Author: Elena Semenovna Belenkaya, Lomonosov Moscow State University, Moscow,
Presenter/First Author Email: elena@dec1.sinp.msu.ru
Presenter/First Author Student?: No
Abstract Body: Planetary magnetospheres are formed by the large-scale current systems. Here we consider magnetospheres of the magnetized planets (Mercury, Earth, Jupiter, and Saturn). Such planets create their intrinsic magnetic field, which is the inner magnetospheric magnetic source. The main permanently existing current systems for Mercury and Earth are the magnetopause currents and the tail currents. Terrestrial magnetosphere possesses also a ring current and field-aligned currents. The giant planets (Jupiter, and Saturn) have very strong own magnetic field, magnetopause and tail currents, field-aligned currents, and additionally a magnetodisc, which in a case of Saturn is called a ring current. Magnetodiscs are formed due to a rapid planetary rotation, large magnetic field, and a presence of the inter-magnetospheric plasma sources. For Jupiter, plasma originates by the Jovian moon Io, for Saturn, by its moon Enceladus. Magnetodics are examples of astrophysical discs in a strong magnetic field. We have shown that in the presence of a strong magnetic field the inner edges of astrophysical discs are located close to the Alfvén radii from the central body regardless of the nature of their origin, material, and motion direction. This concerns to the Jovian and Kronian discs also. Magnetopause currents include current carried by the solar wind charged particles and another one created by the magnetospheric plasma. We have shown that magnetic field can be amplified in the thin transition layer just outside the magnetopause of a rapidly rotating planet (Jupiter). The same mechanism can act in the outer heliosheath just outside the heliopause.

Abstract ID: 94283
Title: Review on the Characteristics of the Plasma/Current Sheet of the Earth's Magnetotail
Presenter/First Author: Anthony Lui, The Johns Hopkins Univ, Laurel, MD
Presenter/First Author Email: tony.lui@jhuapl.edu
Presenter/First Author Student?: No
Published Material: Since the plasma/current sheet of the Earth's magnetotail may be a prototype of plasma/current sheet of the other planets in our solar system, it is important to examine the latest developments on the features of the plasma/current sheet determined from recent satellite missions. In particular, the Earth's magnetotail has been and is surveyed by more satellite missions than the other planets. In this presentation, we shall review some features of the plasma/current sheet that were unknown in the early survey of this region. The implications of the new findings to the dynamics associated with magnetospheric disturbances are discussed.

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Abstract ID: 94307
Title: The Heliospheric Current Sheet: A Review
Presenter/First Author: Edward J Smith, NASA Jet Propulsion Laboratory, Pasadena, CA
Presenter/First Author Email: edward.j.smith@jpl.nasa.gov
Presenter/First Author Student?: No
Published Material: 50% Journal of Geophysical Research
Abstract Body: The earliest in-ecliptic magnetic field measurements revealed the "Sector Structure", regions surrounding the Sun with opposite polarities either Sunward or Outward. The "sector Boundaries" separating these regions were considered to be thin current sheets. A thicker plasma sheet surrounded the boundaries where the solar wind speed and field magnitude reached a minimum and the density a maximum. The first out-of-ecliptic measurements found that the sector structure disappeared demonstrating that the boundary was a single warped current sheet rotating with the Sun and separating coronal magnetic fields from the north and south hemispheres, effectively the heliospheric magnetic equator. The largest current
structure in and beyond the heliosphere, it is variable on time scales from the most rapid magnetic variations to the solar cycle. Scientific interest has continued: connection to the solar-coronal magnetic field, possible reconnection of the oppositely-directed current sheet fields, "closure" of the sheet current at higher latitudes, origin of multiple current sheet crossings, relation to the plasma sheet and to Heat Flux Reversals and Drop-outs, changing inclination of the current sheet over the solar cycle, relation to solar wind Co-rotating Interaction and Rarefaction regions, transport of solar energetic particles and galactic cosmic rays and comparison with magnetospheric current sheets.

Abstract ID: 94340

Title: Current and High-Beta Plasma Sheets in the CIR Shear Zones

Presenter/First Author: Alexander S Potapov, Institute of Solar-Terrestrial Physics SB RAS, Irkutsk,

Presenter/First Author Email: potapov@iszf.irk.ru

Abstract Body: Corotating interaction regions (CIRs) are sheared flow structures formed by impact of the fast solar wind streams on the background slow wind. Similar to coronal mass ejections, CIRs produce magnetic disturbances when interacting with the Earth’s magnetosphere. The paper studies configuration of CIR shear zones using 64-s plasma and 1-s magnetic data from the ACE satellite. The CIR shear zone usually contains the current sheet encased in the plasma sheet. The most striking feature of the CIR structure is a small-scale (3–15 min of convection past a satellite) thin layer or flux microtube of high-beta plasma. Typical proton energy in such a tube is between 5 and 50 eV; proton beta enhancements are very sharp: beta varies by 1 to 2 orders during 1–3 minutes and reaches values up to 60. Most often but not always the high-beta sheet (HBS) coincides with the current sheet which represents the CIR interface. The HBS thickness is much less than that of plasma sheet. On the contrary, the current sheet is usually thinner than the HBS, but often it has a multilayer structure. We can expect that the presence of a thin layer of high-beta plasma creates nonequilibrium configuration in CIR and contributes to the driving of turbulence at the shear zone. The work was supported by RFBR grants 16-05-00631 and 16-05-00056.

Abstract ID: 94368

Title: Local and global impacts of magnetic reconnection at coronal and heliospheric current sheets

Presenter/First Author: Benoit Lavraud, IRAP/CNRS, Toulouse,

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Abstract Body: Recent works have shown the ubiquity of magnetic reconnection in the solar wind. It occurs at current sheets of various types. Although less frequent, its occurrence at the heliospheric current sheet (HCS) and at the front current sheet of coronal mass ejections (CME) is of particular interest. At the HCS, the large-scale topology that follows from reconnection can be studied in detail using suprathermal electron properties. In the second case, the occurrence of reconnection has large-scale implications for the structure of CMEs. Indeed, if reconnection occurs in sufficiently large amounts at the front of CMEs during their propagation from the Sun to Earth, we show that the resulting magnetic flux erosion has a direct and strong
impact on their geo-effectiveness.

**Abstract ID:** 94378

**Title:** Bucking the Current: Connecting Mass Loss Down Jupiter's Magnetotail to the Dawn-Dusk Electric Field at the Io Plasma Torus

**Presenter/First Author:** Jeffrey P Morgenthaler, Planetary Science Institute, Fort Kent, ME

**Presenter/First Author Email:** jpmorgen@psi.edu

**Presenter/First Author Student?:** No

**Co-authors:** Fabiola Pinho Magalhaes, INPE, Sao Jose dos Campos, Brazil; Fabiola Pinho Magalhaes, JPL/NASA/Caltech, Pasadena, CA; Max Marconi, Organization Not Listed, Washington, DC; Max Marconi, Prisma Basic Research, Niagara Falls, NY; Ronald J Oliversen, NASA Goddard Space Flight Center, Greenbelt, MD; Ronald J Oliversen, NASA Goddard SFC, Greenbelt, MD

**Published Material:** About 20% of the data to be discussed was published by Oliversen et al. (2001, JGR). The density enhancement evolution work was presented at the 2015 MOP meeting.

**Abstract Body:** Observations of the Io plasma torus (IPT) reveal a systematic shift of the IPT toward the dawn. Barbosa & Kivelson (1983) showed that this shift is caused by a dawn-to-dusk electric field which is induced by ExB drift when material moves down the magnetotail. The electric field propagates to the region of the IPT by slightly opposing the current in the current current sheet and thus perturbing the magnetic field in the lobes. Precise calculations have yet to be done which would enable a quantitative relationship between the torus shift, measurable with telescopes as small as 28 cm (Nozawa et al. 2004), and the amount of material flowing down the Jovian magnetotail. Renewed motivation for these calculations is provided by the work of Louarn et al. (2014), who suggest that the departure of material down the magnetotail may drive the release of material from the IPT. We have an extensive set of ground-based coronagraphic observations of the IPT (1997 – 2008), which provide both IPT brightness and shift as a function of time. An even larger set (1990 – 2008) of spectroscopic observations of Io in the forbidden oxygen red line provide information on the evolution of density enhancements in the IPT, also a component of the Louarn et al. picture. By quantitatively connecting the amount of material leaving the magnetotail, the response of the total torus brightness, and the evolution of individual IPT density enhancements, we can test the Louarn et al. (2014) hypothesis of what drives radial departure of material from the IPT. The missing piece is a quantitative relationship between the IPT shift and the amount of material leaving the magnetotail. This work could also help determine the amount of material leaving the magnetosphere through the small-scale "drizzle" on the flanks of the magnetosphere, which Bagenal (2007) suggests may make up the bulk of the mass loss to the solar wind and provides motivation for continued synoptic monitoring of the plasma torus and Io volcanic activity.

**Abstract ID:** 94387
Title: Vlasov equilibria for the Force-Free Harris Sheet with any plasma beta

Presenter/First Author: Oliver Allanson, University of St Andrews, St Andrews,

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Co-authors: Thomas Neukirch, University of St Andrews, St Andrews, KY16, United Kingdom; Thomas Neukirch, University of St Andrews, St Andrews, United Kingdom; Thomas Neukirch, Univ St Andrews, St Andrews, United Kingdom; Fiona Wilson, University of St Andrews, St Andrews, United Kingdom; Sascha Troscheit, University of St Andrews, St Andrews, United Kingdom


Abstract Body: We present discussion and analysis of the physical properties of a new exact collisionless equilibrium for a one-dimensional nonlinear force-free magnetic field, namely, the force-free Harris sheet. The solution allows any value of the plasma beta, and crucially below unity, which previous nonlinear force-free collisionless equilibria could not. The distribution function involves infinite series of Hermite polynomials in the canonical momenta, of which the important mathematical properties of convergence and non-negativity have recently been proven. Plots of the distribution function are presented for the plasma beta below unity, and we compare the shape of the distribution function in two of the velocity directions to a Maxwellian distribution.

Abstract ID: 94448

Title: Particle-in-Cell Simulations of Collisionless Magnetic Reconnection With a Non-Uniform Guide Field

Presenter/First Author: Fiona Wilson, University of St Andrews, St Andrews,

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Co-authors: Thomas Neukirch, University of St Andrews, St Andrews, KY16, United Kingdom; Thomas Neukirch, University of St Andrews, St Andrews, United Kingdom; Thomas Neukirch, Univ St Andrews, St Andrews, United Kingdom; Michael Hesse, NASA/GSFC, Greenbelt, MD; Michael Hesse, Space Weather Laborato, Greenbelt, MD

Published Material: This work has been submitted to Physics of Plasmas, but is not yet published.

Abstract Body: Results are presented of a first study of collisionless magnetic reconnection starting from a recently found exact nonlinear force-free Vlasov-Maxwell equilibrium. The initial state has a Harris sheet magnetic field profile in one direction and a non-uniform guide field in a second direction, resulting in a spatially constant magnetic field strength as well as a constant initial plasma density and plasma pressure. It is found that the reconnection process initially resembles guide field reconnection, but that a gradual transition to anti-parallel reconnection happens as the system evolves. The time evolution of a number of plasma parameters is investigated, and the results are compared with simulations starting from a Harris sheet equilibrium and a Harris sheet plus constant guide field equilibrium.

Abstract ID: 94492

Title: The heliospheric plasma sheet: analytical modeling and observations

Presenter/First Author: Roman Anatolevich Kislov, Space Research Institute of the Russian Academy of Sciences (IKI), Moscow,

Presenter/First Author Email: kr-rk@bk.ru

Co-authors: Olga Khabarova, IZMIRAN RAS, Moscow, Russia; Olga Khabarova, IZMIRAN, Troitsk, Moscow, Russia; Helmi V Malova, Scobeltsyn Institute of Nuclear Physics, Moscow, Russia; Helmi V Malova, Space Research Institute RAS, Moscow, Russia

Published Material: Kislov R. A., O. V. Khabarova, H. V. Malova (2015), A new stationary analytical model of the heliospheric current sheet and the plasma sheet, J. Geophys. Res. Space Physics, 120, doi:10.1002/2015JA021294 It was published model with only case of purely dipole magnetic field of the Sun

Abstract Body: Analytical modeling of the heliospheric plasma sheet (HPS) – a structure that surrounds the heliospheric current sheet (HCS) in the solar wind, is an important task, since the HPS origin and its evolution with heliocentric distance is poorly understood both theoretically and observationally.
We develop a single-fluid 2-D analytical model of axially-symmetric thin heliospheric current sheet embedded into the HPS and compare the obtained results with observations. We suggest the HCS-HPS system to be a relatively thin plasma disk that is separated from the Parker solar wind by separatrices at both edges of the HPS. We have found that separatrices represent current sheets as well, which is in agreement with Ulysses observations in the apogee, when it crossed the HCS perpendicular to its plane. Our model employs the differential rotation between the solar photosphere and the corona, which leads to unipolar induction in the corona. Three components of the interplanetary magnetic field (IMF), the solar wind speed, and the thermal pressure are taken into account. The model allows finding spatial distributions of the magnetic field, the speed within the HPS, and electric currents within the HCS. We found that the HPS thickness L decreases with distance r, becoming a constant far from the Sun. L ~2.5 solar radii at 1 AU. The important result is that the IMF spiral may be non-Parker inside the HPS, and even may experience a sharp change of direction under some boundary conditions (Kislov et al., 2015). Additionally, we explore three cases: (i) a purely dipole solar magnetic field of the Sun, (ii) a purely quadrupole magnetic field, and (iii) a mixed case. We show that both the quadrupole and the mixed cases produce additional stable current sheets in the solar wind at higher heliolatitudes, and the last case easily explains the South-North IMF asymmetry.


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**Title:** Evidence for the occurrence of a cylindrical current sheet over the South Pole of the Sun

**Presenter/First Author:** Olga Khabarova, IZMIRAN, Troitsk, Moscow,

**Presenter/First Author Email:** habarova@izmiran.ru

**Co-authors:** Roman Anatolevich Kislov, Space Research Institute of the Russian Academy of Sciences (IKI), Moscow, Russia; Helmi V Malova, Scobeltsyn Institute of Nuclear Physics, Moscow, Russia; Helmi V Malova, Space Research Institute RAS, Moscow, Russia

**Published Material:** The observational part (30%) was presented at EGU16 - abstract no. EGU2016-18076

**Abstract Body:** A cylindrical current sheet was observed inside a fast speed stream from the coronal hole during the passage of Ulysses over the South solar pole in December 2006 – January 2007, when it reached maximal heliolatitude of 79.7 deg at 2.4 AU. It was characterized by sharp changes in the solar wind and IMF parameters, characteristic for cylindrical or conic-like current sheets. Interestingly, both the solar wind velocity and the density sharply decreased, but the temperature was twice as large in the point closest to the pole. We discuss solar origin of the observed structure and present modeling that can explain the observations. We develop the model of a cylindrical current sheet that surrounds a coronal hole. Modeling shows that such a sheet might experience pinching with multiplication of the structure. One of the smaller-size tubes might be observed by Ulysses. We also consider a case of streamer- and jet-like structures, as well as the possibility of formation of a relatively small cylindrical current sheet near the pole due to non-axiality of the solar rotation axis and the magnetic axis. According to polar oval observations, similar structures are sometimes formed in the terrestrial cusps during the development of geomagnetic storms.

**Abstract ID:** 94508

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**Title:** The Mars Magnetotail Current Sheet: ionospheric control of its systematic variation

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**Published Material:** 0% presented or published elsewhere

**Abstract Body:** Because Mars has no internal dipole magnetic field, the planetary magnetotail is created by draped interplanetary magnetic field. For a nominal Parker spiral IMF, the tail current sheet is aligned with the z axis, rather than the y axis as at Earth. The draping field is caused by the viscous interaction of the solar wind and IMF as they directly interact with the topside ionosphere. This study demonstrates, through analysis of magneto-hydrodynamic simulation results, that there is a systematic asymmetry in the y location of the tail current sheet. For high solar flux conditions (i.e., solar maximum), the duskside magnetotail lobe is larger and the current sheet is offset in the −y (dawnward) direction. As with Venus, this
configuration is caused by the azimuth angle of the IMF impacting the planet, allowing the field lines to remain in the lobe farther downtail on the duskside than on the dawnside. At solar minimum, the case is reversed, with the current sheet offset in the +y (duskward) direction. The weaker ionosphere at solar minimum allows for a deeper penetration of the magnetic pileup region on the dayside, increasing the viscous interaction and hampering IMF field line slippage past the planet. The s-shaped curvature of the magnetic field lines on the dayside preferentially intensifies the field intensity of that lobe, shifting the location of the current sheet.

Abstract ID: 94510

Title: Dynamics of the current sheet in Earth's magnetotail by the impact of an interplanetary shock

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Abstract Body: Earth’s magnetosphere is strongly disturbed by the impact of an interplanetary shock. In this study we report the dynamics of the current sheet in the near-Earth magnetotail at ~17 RE observed by the Cluster spacecraft when an interplanetary shock impacted Earth’s magnetosphere. Right after the storm sudden commencement (SSC) induced by the impact the current density, estimated by the curlometer technique using the Cluster constellation, strongly enhanced, which represents the thinning of the current sheet. Along with the thinning the density and temperature of the plasmas significantly increased and earthward bursty flows occurred. However, there was no signature of dipolarization of the magnetic field. About 20 minutes later Cluster entered a region with very small current density while maintaining the enhanced density and temperature of the plasmas. Then, about an hour after the SSC strong fluctuations of the current sheet with dipolarization started, which was associated with sudden drop of the AL index on the ground. This observation implies that the compression of the magnetosphere associated with the SSC almost simultaneously occurs over large regions from the inner magnetosphere to the near-Earth magnetotail. However, the activity associated with substorms may occur with some time delay.

Abstract ID: 94570

Title: On the nature of 3D current layers in the solar atmosphere

Presenter/First Author: Clare E Parnell, University of St Andrews, St Andrews, KY16

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Co-authors: Julie Stevenson, University of St Andrews, St Andrews, United Kingdom

Abstract Body: Electric currents are pervasive throughout the solar atmosphere. However, when strong concentrations of currents arise, the dynamic behaviour of the magnetic field and plasma can completely change giving rise to significant releases of magnetic energy. As such understanding how and where current layers form is essential to both understanding and predicting magnetic-energy-release events. In this talk, I will focus on the formation of three-dimensional current layers: both where and how they may form. The differences between current layers in low and high beta magnetohydrostatic equilibria will be discussed. Finally I will briefly touch on the evolution of a current layer once magnetic reconnection is initiated.
FIELD-ALIGNED CURRENTS

Abstract ID: 94315
Title: Temporal Stability of Field-Aligned Currents and Electric Fields in the Auroral Oval
Presenter/First Author: Tomas Karlsson, Royal Institute of Technology, Stockholm,
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Presenter/First Author Student?: No
Co-authors: Madalin Ivan, KTH Royal Institute of Technology, Stockholm, Sweden

Abstract Body: The Cluster magnetic field data from several years’ worth of aurora oval crossing is used to quantify the temporal variations of magnetic field signatures of field-aligned currents (FAC). The method is used to study the cross-correlation between pairs of spacecraft as a function of the temporal separation of the auroral crossings of the respective spacecraft. When the method is applied on the large-scale variations associated with the whole auroral pass, it gives results consistent with those of an earlier smaller study using low-altitude measurements of particle fluxes. We then apply the method to study the temporal stability of FAC as a function of latitude, local time, geomagnetic parameters, and the scale sizes of the magnetic field variations. This is contrasted to the temporal stability of electric fields, studied by the same methodology. The FACs and electric fields show similarities in the dependence of temporal stability on location and other parameters, but the stability of the electric fields is consistently smaller than that of the FACs. We discuss some conclusions of this study, in particular as it applies to the nature of auroral acceleration structures.

Abstract ID: 94349
Title: Closure of the Auroral Current Loop.
Presenter/First Author: Stephen B Mende, Univ California, Berkeley, CA
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Presenter/First Author Student?: No
Published Material: 25%

Abstract Body: How the magnetosphere processes electro-dynamic energy and creates quiescent auroras on closed field line regions is a central question in magnetospheric physics. In a commonly accepted simple model azimuthal pressure gradients produce radial currents in the magnetosphere and parts of these currents are shunted through field-aligned currents (FACs) and then Pedersen currents in the ionosphere. In an example where the field aligned currents were measured by FAST and Polar satellites we have shown that typical azimuthal pressure gradients are adequate to generate the magnetospheric $B_{perp}$ currents to produce the observed FACs. However to power the aurora the $B_{perp}$ currents from the magnetospheric generator have to turn into FACs. In the magnetosphere the FACs are produced by the divergence of the $B_{perp}$ currents [Vasyliunas, 1970]. It can be shown that the $B_{perp}$ divergence is caused by the non-uniformity in the magnetic field magnitude. If the generator current is radially earthward directed (dusk sector) then the gradient of the field magnitude has to be directed outward for the divergence to produce the upward Region 1 currents. The location of these Region 1 currents are thought to be where the dusk side auroral arcs occur. Such outward $B$ field gradients would be reversed from the magnitude gradients of the Earth main field. There are several components of the tangential currents that could cause outward $B$ magnitude gradients. Using Cluster satellite measurements we calculated field magnitude gradients, their direction and magnitude searching for regions with outward magnetic field magnitude gradients. It should be noted that the reversal of plasma pressure gradients could also occur, which would also create the correct divergence for upward FACs however pressure gradient reversal would also reverse the magnetospheric dynamo current and would invalidate the simple model of the radially inward currents on the duskside.

Abstract ID: 94379
Title: Substorm Current Wedge Composition by Wedgelets, Small Pieces of FACs supported by Dipolarization Fronts
Presenter/First Author: Jiang Liu, University of California Los Angeles, Los Angeles, CA
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Co-authors: Vassilis Angelopoulos, UCLA, Los Angeles, CA; Vassilis Angelopoulos, UCLA, EPSS/IGPP, Los Angeles, CA; Vassilis Angelopoulos, University of California Los Angeles, Los Angeles, CA; Xiangning Chu, University of California Los Angeles, Los Angeles, CA; Xuzhi Zhou, Peking University, Beijing, China; Xuzhi Zhou, University of California Los Angeles, Los Angeles, CA; Chao Yue, University Corporation for Atmospheric Research, Boulder, CO; Chao Yue, University of California Los Angeles, Los Angeles, CA; Chao Yue, Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles,
Published Material: 90% of the material has been published on Journal of Geophysical Research and Geophysical Research Letters.

Abstract Body: The substorm current wedge (SCW) is the major field-aligned current (FAC) system of the substorm process, so understanding the SCW is crucial to comprehending the substorm phenomenon. Our recent studies suggest that the SCW could be a collective effect of small-scale FACs carried by dipolarization fronts. Our statistical analysis of THEMIS data showed that the FACs inside the DF layer are directed towards (away from) Earth at the DF’s morning (evening) flank, in a region-1 sense. These FACs are in similar configuration to the SCW’s region-1 sense FACs, although a DF, and thus its FACs, are only ~1 RE wide, much smaller than a SCW which is several-hours-of-MLT wide. The amount of FAC contained by each DF is also much fewer than that of a SCW. We therefore term the FACs of each DF as a wedgelet, a building element of the SCW.

However, it is unclear how these localized wedgelets can collectively form a large-scale SCW. Because each wedgelet contains a pair of oppositely directed FACs, neighboring wedgelets will cancel each other’s FACs. The total FAC of many such wedgelets will still be too small to account for an SCW. To solve this problem, we examine the DF’s FACs with a more comprehensive statistical study and found that they are asymmetric: in the dawn (dusk) sector of the magnetotail, a wedgelet has more FAC toward (away from) the Earth than away from (toward) the Earth, so the net FAC is toward (away from) the Earth. In this way, neighboring wedgelets will not cancel each other’s currents, and it takes only ~10 wedgelets to form a typical substorm current wedge.

The attached figure illustrates our scenario that the collective effect of many asymmetric wedgelets is a substorm current wedge.
The European Space Agency's three Swarm satellites, in orbit since late 2013, provide precise, multi-point measurements of electric and magnetic fields from circular polar orbits. When used in conjunction with ground-based camera arrays including the THEMIS white-light cameras, the number of satellite-ground conjunctions is large and growing, and is providing an unprecedented number of opportunities to explore the detailed relation between field-aligned currents and auroral forms. In this study we focus on two specific morphologies, namely pulsating auroras and multiple, parallel auroral arcs. We find that pulsating auroras are essentially always accompanied by FAC fluctuations having amplitudes comparable to those found within discrete arcs: several μA/m². The ubiquity and intensity of these currents raise the question of the degree to which electrodynamic coupling to the ionosphere affects the formation and evolution of pulsating patches. In the case of multiple, parallel discrete arcs, we ask the question of whether multiple arc systems represent a collection of multiple up/down current pairs, or whether instead each arc is an intensification within a broad, unipolar current sheet.

This research is supported by the Canadian Space Agency and the European Space Agency

**Abstract ID:** 94389

**Title:** Field-aligned current distribution at high latitude: Results from the Swarm satellite constellation

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**Abstract Body:** ESA's constellation mission Swarm provides the opportunity to derive more reliable FAC estimates from multi-satellite magnetic field measurements. We make use of the Swarm A/C satellite pair, which flies side-by-side at a separation of 1.4° in longitude. By considering along-track differences over 5 s the four readings at the corners of an almost symmetrical quad are used for calculating the mean vertical current density flowing through the encircled area. FACs are estimated by mapping the vertical current component onto the field direction. Within the auroral oval current estimates from single and dual-satellite solutions agree generally well. Significant differences are frequently observed in the polar cap. Here underlying assumptions for single-satellite solutions are obviously not well satisfied. We compare these polar cap FACs with observations from other satellites. FACs do appear preferably during times of northward IMF, and by seems to play an important role. Other supporting observations come from DMSP satellites. Their particle data and auroral images help to identify the region in the magnetosphere where the FACs are connected to.

**Abstract ID:** 94391

**Title:** Dynamic effects of restoring footpoint symmetry on closed magnetic field-lines: Asymmetric Birkeland currents

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**Published Material:** 80 % presented as poster on AGU 2015, 80 % in revision in JGR

**Abstract Body:** We present an event where simultaneous global imaging of the aurora from both hemispheres reveals a large longitudinal shift of the nightside auroral features of about 3 h, being the largest shift reported on from conjugate auroral imaging. This is interpreted as evidence of highly twisted field-lines. We attribute this large shift to the combined effect of a persistent positive y-component of the interplanetary magnetic field before and during the event, and the positive dipole tilt angle (summer in Northern Hemisphere). At the same time, the Super Dual Auroral Radar Network (SuperDARN) observes the nightside Harang region in both hemispheres. In addition to confirm the large longitudinal shift between the two hemispheres, the radar data indicate a faster flow towards the dayside in the dusk cell in the Southern Hemisphere compared to its conjugate region. We interpret this as a signature of untwisting of the closed magnetic field-lines, a process that acts to restore magnetic footpoint symmetry. The event is
analysed with emphasis on the field-aligned Birkeland Currents (BC) associated with this rectification process as previously suggested. Using data from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) during the same conditions as the presented event, the large-scale BC pattern associated with the event is presented. It shows the expected influence of this process on BCs, namely stronger currents in the region of the untwisting process, representing a mechanism for asymmetric BCs, relevant for understanding hemispheric differences in the M-I coupling.

Abstract ID: 94408

Title: Magnetosphere-Ionosphere Coupling and the Evolution of Field-Aligned Currents

Presenter/First Author: Robert L Lysak, University of Minnesota Twin Cities, Minneapolis, MN

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Co-authors: Yan Song, University of Minnesota Twin Cities, Minneapolis, MN; Murray D Sciffer, University of Newcastle, Callaghan, Australia; Colin L Waters, Osaka Electro-Communicat. Univ, Osaka, Japan; Colin L Waters, University of Newcastle, Callaghan, Australia

Abstract Body: Changes in field-aligned currents are mediated by the propagation of shear Alfvén waves along geomagnetic field lines. The interaction of Alfvén waves with the ionosphere results in the reflection and/or absorption of these waves, depending on the ionospheric conductance. The ionospheric Hall conductivity couples shear Alfvén waves to compressional waves, modifying the reflection coefficient and leading to the ground signatures of these currents. While current continuity implies that only gradients of the Hall conductivity are important, the more complete inductive ionosphere model shows that even a uniform Hall conductivity affects the reflection of Alfvén waves and thus the structure of the field-aligned currents. Multi-satellite observations from missions such as Cluster and Swarm can lead to a better understanding of the fine-scale structure of these field-aligned currents. These interactions will be illustrated by means of a three-dimensional model for the propagation of MHD waves in the dipolar regions of the magnetosphere that includes conductivity differences between day and night sides. In particular, near the terminator under solstice conditions quarter-wave modes can be excited due to the difference in conductivity in the two hemispheres.

Abstract ID: 94416

Title: On the Ionospheric Closure of Field-Aligned Currents and its M-I Coupling Implications

Presenter/First Author: Octav Marghitu, Institute of Space Sciences, Bucharest,

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Published Material: Parts of the material were published in JGR, Marghitu et al. (2004, 2009, 2011).

Abstract Body: More than 50 years ago, Boström (1964) suggested two different configurations for the current system associated with an auroral arc: In ‘case 1’, field-aligned current filaments at the ends of the arc are connected by a Cowling electrojet along the arc, driven by a longitudinal (essentially E-W) electric field and a magnetospheric generator dominated by electric fields and currents in azimuthal direction. In ‘case 2’, field-aligned current sheets at the sides of the arc are connected by Pedersen current across the arc, driven by a meridional (essentially N-S) electric field and a magnetospheric generator dominated by electric fields and currents in radial direction; in this case a divergence free Hall electrojet flows along the arc. Since this early paper, written before the actual discovery of the field-aligned currents by in-situ magnetic field measurements, the ‘case 2’ configuration was found to be associated with quiet auroral arcs and, on a larger scale, with the Region1 / Region2 current system of the quiet auroral oval. Dynamic magnetospheric phenomena, like the magnetosphere-ionosphere (M–I) coupling of bursty bulk flows or, on a larger scale, the substorm current wedge, appear to be associated rather with the ‘case 1’ configuration. In the real world, the two configurations can become entangled, either by preserving their basic features (e.g. embedded in each other, in particular during disturbed times), or by being mixed up in a new, hybrid configuration, with sheet-like field-aligned currents (‘case 2’) coupled to a divergent electrojet (‘case 1’). Observational evidence and theoretical results suggest that this hybrid configuration could be associated with the substorm growth phase, perhaps providing the transition between ‘case 2’ and ‘case 1’.

Abstract ID: 94420

Title: THEMIS Observations of Plasma Sheet Region 1 and 2 Birkeland Currents in Quiet and Substorm Times

Presenter/First Author: Jiang Liu, University of California Los Angeles, Los Angeles, CA

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Presenter/First Author Student?: No
Abstract Body: Although region 1 and 2 Birkeland currents are closely related to geomagnetic activities such as substorm initiation, their magnetospheric origin remains not well known. We look for the origin of nightside Birkeland currents using multi-point observations from THEMIS in the 8-12 RE downtail region. Our statistical study reveals that region 1 and 2 currents exist in the plasma sheet at both quiet and active times. The region 2 current is buried deep inside the plasma sheet (this is found for the first time), whereas the region 1 current is farther away from the neutral sheet, extending to the plasma sheet boundary layer. At geomagnetic quiet times, the separation layer between the region 2 and 1 currents is located at ~2.5 RE from the neutral sheet. During substorms, the separation layer migrates towards (away from) the neutral sheet when the plasma sheet thins (thickens). These findings suggest that the plasma sheet is a source of region-1 and -2 Birkeland currents regardless of geomagnetic activity level, and its evolution controls the distribution of FACs in the magnetotail.

Abstract ID: 94422

Title: Statistical investigation of ionospheric density depletions at the boundary of auroral precipitation: EISCAT observations

Presenter: Maria Hamrin, Umea Univ, Umea,

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First Author: Timo Pitkänen, University of Oulu, Oulu,

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Abstract Body: Ionospheric electron density depletions are often observed at the boundaries of auroral precipitation. Previous investigations suggest that these depletions, known also as auroral density cavities, are associated with a downward field-aligned current (FAC) region within the localized auroral current system. While precipitating electrons carry an upward FAC, the density depletions have been explained to be created by upgoing ionospheric electrons carrying the downward FAC. Enhanced perpendicular ionospheric electric fields are suggested to the FAC closure and they have been observed to be associated with the depletions. In this investigation, we use field-aligned measurements from the EISCAT UHF incoherent scatter radar from the years 2001-2011 to statistically study ionospheric density depletion events associated with auroral precipitation. We investigate the occurrence of the density depletions and study their dependence on geomagnetic activity as well as their general statistical properties.

Abstract ID: 94424

Title: Substorm currents and Cowling channels

Presenter/First Author: Ryoichi Fujii, Nagoya Univ, Nagoya,

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Published Material: I am requested to overview and review substorm currents and Cowling channels by the conveners. Hence most of materials that will be presented already were published in Journals such as J. Geophys. Res. and Ann. Geophysicae.

Abstract Body: The talk will give a brief overview of the magnetosphere-ionosphere (M-I) coupling during substorms seen in the ionosphere, particularly that of the distributions of macro- and meso-scale field-aligned currents (FACs), auroras and associated electrodynamic parameters such as the electric field and the ionospheric conductance. These physical quantities are adjusted to each other spatially and temporarily in a physically consistent manner, which is the essence of the M-I coupling. The Cowling channel mechanism first invented in connection with the solar atmosphere is one of the most fundamental processes of the M-I coupling, describing which extent the divergence of the Hall current at the inhomogeneity of the Hall conductance can be connected to the Pedersen current with producing excess space charges and hence polarization electric field (ionospheric closure) or to FACs flowing into/from the magnetosphere (magnetospheric closure). The talk will show extensive efforts to understand the Cowling channel mechanism and to determine the ratio between the amounts of the two closure currents, and its applications to the substorm currents and pulsating auroras.
Abstract ID: 94426

Title: Field-Aligned Plasma Transport Induced by Alfvén Wave as a Mechanism of TEC Modulation by Pc5 Pulsations

Presenter/First Author: Viacheslav Pilipenko, Space Research Institute, Moscow,

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Published Material: 20%

Abstract Body: Monitoring of the ionospheric total electron content (TEC) variations by global satellite navigation system GPS has turned out to be a sensitive method to study the propagation of transient disturbances in the ionosphere, induced by internal gravity waves and magnetohydrodynamic (MHD) waves. However, the effect of TEC modulation by MHD waves is not well examined and a responsible mechanism has not been firmly identified. During periods with intense global Pc5 waves during the recovery phase of strong magnetic storms distinct pulsations with the same periodicity were found in the TEC data from high-latitude GPS receivers. We analyze jointly signatures of Pc5 pulsations in the TEC/GPS, ionospheric radar (EISCAT), and ground magnetometer data. Comparison of periodic fluctuations of the electron density at different altitudes from EISCAT shows that main contribution into TEC pulsations is provided by the lower ionosphere, namely the E- and lower F-layers. This observational fact favors the TEC modulation mechanism by field-aligned plasma transport induced by Alfvén wave. Numerical modeling supports the conjecture that TEC modulation is caused by periodic pumping/depleting the ionospheric plasma density by the field-aligned current between the magnetosphere and ionosphere transported by Alfvén wave.

Abstract ID: 94429

Title: Statistical Analysis of Vortex-driven Field-Aligned Currents

Presenter/First Author: Andreas Keiling, Space Sciences Laboratory, Berkeley, CA

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Abstract Body: The substorm current wedge (SCW) is a current system that forms during substorms, and electrically couples the near-Earth plasma sheet in the nightside with the ionosphere via field-aligned currents. These field-aligned currents cause a multitude of phenomena during the course of a substorm, one of which is the substorm-related aurora. An understanding of the formation of this current system is of key importance for an understanding of the substorm phenomenon as a whole. Large-scale plasma flow vortices in the near-Earth space environment have been shown to contribute to the field-aligned current of the SCW. While it has been argued that they do not provide the bulk current of the SCW, they are nevertheless an important "ignitor" of the SCW. Using multipoint measurements from the THEMIS fleet, we investigated the statistical relationship among spatial dimension, duration and associated current density of these plasma flow vortices during times of substorm.

Abstract ID: 94434

Title: Magnetosphere-Ionosphere Coupling at Earth, Jupiter, and Saturn

Presenter/First Author: Licia C Ray, University College London, London,

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Published Material: I have been invited to give a review talk, so much of the presentation will be an introduction to compare and contrast the different systems.

Abstract Body: Magnetosphere-ionosphere (M-I) coupling occurs at every planet with a substantial atmosphere and magnetic field. Field-aligned currents communicate energy and angular momentum between the two regions, often resulting in bright auroral emissions. At Earth, field-aligned currents are predominately driven by the interaction of the solar wind with the magnetosphere. In the plasma-laden magnetospheres of Jupiter and Saturn, field-aligned currents convey angular momentum from the planet to its surrounding plasma disc in an attempt to maintain rigid corotation.
between the two regions. I will review the drivers of and limitations to M-I coupling at Earth, Jupiter, and Saturn, and discuss how these limitations affect our ability to model the complete coupled system.

**Abstract ID:** 94436

**Title:** The Bow Shock Current System

**Presenter/First Author:** Ramon E Lopez, University of Texas at Arlington, Arlington, TX

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**Published Material:** 50% of this material has been published in JGR and JASTP. Presentations on the published material was made at AGU (2009) and Isradynamics (2010).

**Abstract Body:** As the solar wind crosses the bow shock, it is compressed and heated. The compression produces a magnetic shear across the bow shock, thus a current flows along the shock. This current must be closed through currents that flow through the magnetosheath and connect to magnetopause boundary currents and Birkeland currents that close in the ionosphere. In this paper I will examine the dynamical role of this current system in solar wind-magnetosphere coupling.

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**Abstract ID:** 94445

**Title:** The Relationship Between the Ionospheric Current System and Magnetic Field Perturbations on Ground and in Space

**Presenter/First Author:** Karl Laundal, University of Bergen, Bergen,

**Presenter/First Author Email:** karl.laundal@ift.uib.no

**Published Material:** 60% at AGU fall meeting and GRL paper

**Abstract Body:** We investigate how the global ionospheric current system and associated magnetic field perturbations depend on sunlight. We use magnetic field measurements from ground and from low Earth orbiting satellites CHAMP and Swarm to calculate global maps of the ionospheric current system at polar latitudes. Ground magnetometers can be used to calculate the horizontal equivalent current at high latitudes. Measurements from low Earth orbit can provide both the horizontal equivalent (divergence-free) current and the field-aligned (Birkeland) currents. Statistical maps of the global current systems show that the relationship between the equivalent horizontal current, the actual horizontal current, and the Birkeland current is different in darkness and sunlight. In the polar cap, the equivalent current tends to be anti-parallel to the horizontal curl-free currents in darkness but not in sunlight. In sunlight, the equivalent current is typically anti-parallel to the convection, indicating that the Hall current system dominates. Thus on average the ground magnetic field in the polar cap is dominated by different current systems in sunlight and in darkness. Consequently large inter-hemispheric differences in high-latitude magnetic field perturbations can be expected, particularly during solstices.

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**Abstract ID:** 94447

**Title:** Asymmetric field aligned currents into the conjugate hemispheres

**Presenter/First Author:** Nikolai Østgaard, University of Bergen, Bergen,

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**Co-authors:** Paul Tenfjord, University of Bergen, Bergen, Norway; Jone Reistad, University of Bergen, Bergen, Norway; Karl Laundal, University of Bergen, Bergen, Norway; Stein Haaland, Birkeland Centre for Space Science, Bergen, Norway; Stein Haaland, University of Bergen, Bergen, Norway; Stein Haaland, Max-Planck Institute, Goettingen, Germany; Kristian Snekvik, University of Bergen, Bergen, Norway; Steve E. Milan, University of Bergen, Bergen, Norway; Steve E. Milan, University of Leicester, Leicester, United Kingdom
Abstract Body: From simultaneous conjugate auroral imaging we have learned that when IMF has a By component, the auroral features in the two hemispheres will not be at the nominal conjugate foot points. The displacement of foot points are strongly correlated to the IMF By or clock angle, which implies that there is a By component on the closed field line as well. From modeling efforts we have learned that the By component in the closed magnetosphere is not a result of IMF By ‘penetration’ but is induced by the asymmetric pressure in the lobes when the IMF has a By component. This magnetic stress associated with the the induced By component will be released asymmetrically into the conjugate ionospheres and give rise to asymmetric Alfvén aurora and currents consistent with the different convection patterns. Some studies indicate that it will take an hour or more to induce this By component and consequently asymmetric foot points. Our own investigations based on auroral imaging and modeling indicate that this is established after 10-20 minutes.

Auroral imaging of the two hemispheres has also shown that there is a statistical significant brightness difference in the dusk side polar aurora correlated with an IMF Bx component. We have interpreted this difference in terms of a difference in solar wind dynamo in the two hemispheres. Although this effect is weak, the accumulated effect might be significant.

Abstract ID: 94449

Title: Principal Component Analysis of Birkeland Currents Determined by the Active Magnetosphere and Planetary Electrodynamics Response Experiment

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Published Material: The work is a follow-on study to a paper published in JGR in 2015. About 25% of the material is previously published

Abstract Body: Principle Component Analysis is performed on Birkeland or field-aligned current (FAC) measurements from the Active Magnetosphere and Planetary Electrodynamics Response Experiment [AMPERE]. PCA identifies the patterns in the FACs that respond coherently to different aspects of geomagnetic activity. The region 1 and 2 current system is shown to be the most reproducible feature of the currents, followed by cusp currents associated with magnetic tension forces on newly-reconnected field lines. The cusp currents are strongly modulated by season, indicating that their strength is regulated by the ionospheric conductance at the foot of the field lines. PCA does not identify a pattern that is clearly characteristic of a substorm current wedge. Rather, a superposed epoch analysis of the currents associated with substorms demonstrates that there is not a single mode of response, but a complicated and subtle mixture of different patterns.

Abstract ID: 94457

Title: Intense Localised Currents during the St. Patricks Day Magnetic Storm, March 17, 2015

Presenter/First Author: Hermann J Oppegnoorth, Swedish Inst. of Space Physics, Uppsala,

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Published Material: 5 % (basic Solar wind, AE index and example Miracle magnetograms during Swedish American Space Symposium, Washington DC, October 5, 2015)

Abstract Body: The St. Patrick’s day Storm on March 17, 2015 was a text-book example of a two phase magnetic storm initiated by an interaction between a CIR shock front and a CME at 1 AU, causing a two phase magnetic storm at Earth. While the first part of the magnetic storm is relatively smooth in its magnetic signatures the second part contains a number of very short-lived magnetic spikes of the order of 1-2000 nT for as short as 3-5 minutes at auroral and sub-auroral latitudes. The dB/dt effect of these spikes is causing induced electric fields of the order of several hundred mV/km at
ground level, which is of the order of earlier events like during the Halloween storm, which had recorded damaging effects on ground-based technology systems.

We will analyse the difference in magnetospheric activity and solar wind drivers between the two markedly different storm phases and discuss possible physical reasons for the spikes occurring in the second phase. Ground-based data from the Scandinavian sector reveals that these features are indeed very localised, of the order of 1000 km or so, and thus they must, just like similarly sized substorm onset features, be associated with violent localised field-aligned currents.

Abstract ID: 94467

Title: SWARM Satellite and EISCAT Radar Observations of Auroral Arcs and Field-Aligned Currents

Presenter/First Author: Anita Taina Aikio, University of Oulu, Oulu,

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Abstract Body: We study the SWARM satellite passes over night sector auroral arcs that are measured by the incoherent scatter EISCAT UHF and VHF radars in Tromsø (67° cgmLat). The auroral arcs are observed optically by ground-based all-sky cameras. The electrodynamics of these arcs will be studied. Of special interest is one of the events during the Finnish EISCAT-SP experiment on 9 November 2015, when the auroral arc appears in the field-aligned UHF radar beam at the same time as the SWARM A and C fly over the Tromso magnetic field lines. The auroral differential electron energy flux is estimated from the radar-measured electron density altitude profiles. The spectral shape resembles inverted-V type. The field-aligned current carried by these down-coming electrons is calculated and it will be compared to the field-aligned current estimated from the data provided by the vector magnetic field instruments of SWARM. In addition, the tri-static VHF radar measurement yields the F-region electric field and it will be compared to the electric field provided by the EFI instrument of SWARM. The VHF radar shows high F-region ion temperatures located adjacent to the auroral arc, indicating large electric fields. While the EISCAT radars provide a local measurement of the electrodynamic parameters, the SWARM satellites yield measurements over a large latitudinal span of the night sector auroral oval.

Abstract ID: 94472

Title: The Morphology of the Birkeland Current System During Substorms

Presenter/First Author: John Coxon, University of Southampton, Southampton,

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Abstract Body: Birkeland (field-aligned) currents link the magnetopause to the ionosphere, communicating stresses through the system. In the case of substorms, field-aligned currents are enhanced as a result of cross-tail current disruption in the tail. Global-scale current maps can be obtained from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE). To identify the morphology of the field-aligned currents close to substorm onset it is necessary to correctly identify the time, latitude and longitude of onset. We perform a superposed epoch analysis of the morphology of the Birkeland currents during substorms accounting for all relevant temporal and spatial boundaries. We use substorm expansion phase onsets identified using the Substorm Onsets and Phases from Indices of the Electrojet [SOPHIE] technique and calculate average current maps of the current systems for two hours prior, and subsequent, to onset. We bin the onsets by the latitude of the current oval at onset, and we rotate each current map by the MLT at which the substorm onset was recorded.

In this way, we investigate the spatial and temporal characteristics of the currents flowing during a substorm. We observe a large-scale structuring in the currents in the same sense as the substorm current wedge, in contrast to previously reported studies. Furthermore, we do not see any statistical signature in these current systems that is consistent with a drop in the current magnitude prior to auroral dimming, as
reported in the literature. We discuss this result in the context of other recent studies of the spatial studies of Birkeland currents during substorms with which we differ and discuss reasons as to why this may be the case.

Abstract ID: 94477

Title: In situ spatio-temporal measurements of the detailed azimuthal substructure of the substorm current wedge

Presenter: Licia C Ray, University College London, London,

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Abstract Body: The substorm current wedge (SCW) is a fundamental component of geomagnetic substorms. Models tend to describe the SCW as a simple line current flowing into the ionosphere toward dawn and out of the ionosphere toward dusk, linked by a westward electrojet. We use multispacecraft observations from perigee passes of the Cluster 1 and 4 spacecraft during a substorm on 15 January 2010, in conjunction with ground-based observations, to examine the spatial structuring and temporal variability of the SCW. At this time, the spacecraft traveled east-west azimuthally above the auroral region. We show that the SCW has significant azimuthal substructure on scales of 100 km at altitudes of 400–7000 km. We identify 26 individual current sheets in the Cluster 4 data and 34 individual current sheets in the Cluster 1 data, with Cluster 1 passing through the SCW 120–240 s after Cluster 4 at 1300–2000 km higher altitude. Both spacecraft observed large-scale regions of net upward and downward field-aligned current, consistent with the large-scale characteristics of the SCW, although sheets of oppositely directed currents were observed within both regions. We show that the majority of these current sheets were closely aligned to a north-south direction, in contrast to the expected east-west orientation of the preonset aurora. Comparing our results with observations of the field-aligned current associated with bursty bulk flows (BBFs), we conclude that significant questions remain for the explanation of SCW structuring by BBF-driven "wedgelets." Our results therefore represent constraints on future modeling and theoretical frameworks on the generation of the SCW.

Abstract ID: 94478

Title: Coordinated Swarm and EISCAT Svalbard Radar observations of the cusp ionosphere

Presenter/First Author: Frederic Pitout, Toulouse University, Toulouse,

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Presenters Student?: No

Co-authors: Xi Bai, IRAP, Toulouse, France; Pierre-Louis Blelly, IRAP, Toulouse, France; Aurelie Marchaudon, IRAP, Toulouse, France

Abstract Body: We present a case study involving the EISCAT Svalbard Radar (ESR) sounding the cusp ionosphere while the Swarm fleet flew through its beam. ESR data show strong electron temperatures, generally ascribed to soft electron precipitation, and a structured electron density possibly due to pulsed reconnection at the magnetopause. The particle sensors on board Swarm record much shorter-scale electron and ion structures, revealing the actual size of particle injection region and that of the corresponding region affected by enhanced convection. Magnetic field measurements also give us the field-aligned current (FAC) density, with which we infer the electron heating due to the thermoelectric effect in the upward FAC part. We are thus able to separate the contribution of the electron precipitation and that of the FAC, both responsible for the net heating of the ionospheric thermal electron population.

Abstract ID: 94484
Abstract Body: Local time resolved dynamics of field-aligned currents and their response to solar wind variability

Abstract ID: 94488

Title: Multi-satellite and Conjugate Ground-based Studies of Magnetosphere-Ionosphere Coupling at Substorm Expansion Phase Onset

Abstract Body: The explosive release of energy within a substorm marks the beginning of one of the most dynamic and energetically significant processes in the coupled solar-terrestrial system. Stored magnetic energy is quickly converted to plasma kinetic energy, resulting in dramatic changes in the large-scale magnetic topology of the Earth’s nightside magnetic field and in increases of the flux of energetic particles in near-Earth space, generating an apparently repeatable time series of events in the dynamic aurora, spanning many degrees of latitude and hours of local time. Whilst the processes leading to energy storage in the magnetotail are well-understood, the conditions which lead to rapid energy release rather than a more gradual dissipation of stored energy remain very poorly so. Here we examine the potential role of magnetosphere-ionosphere coupling (MIC), facilitated by field-aligned currents, in triggering large scale morphological changes in the magnetotail across many hours of local time. We present ground-based magnetometer and all-sky imager observations combined with conjugate in-situ observations of the magnetic fields and temperature anisotropies of electrons and ions from GOES, as well as the NASA Van Allen Probes and THEMIS satellites. By utilising the extensive ground coverage available from the CARISMA magnetometer and THEMIS All-Sky Camera arrays we resolve longitudinal and relative timing uncertainties between the measurement platforms at onset. We seek to establish a causal sequence of events and thereby examine especially the potential role of near-Earth MIC processes in the substorm sequence, particularly that of the Akasofu auroral evolution at onset – independent of whether this precedes or follows the onset of magnetic reconnection at the near-Earth neutral line.

Abstract ID: 94498

Title: Characteristics of high-latitude auroral arcs

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Title: Characteristics of high-latitude auroral arcs
Abstract Body: During quiet times, field-aligned currents appear frequently far poleward of the main auroral oval, causing high-latitude (polar) auroral arcs. It is well-established that they occur preferably during northward IMF conditions and their location and motion is strongly influenced by the sign of IMF Bz. The role of IMF Bz is less clear: Many studies indicate a weak dependence of high-latitude currents and polar arcs on negative (positive) IMF Bz in the northern (southern) hemisphere, other studies do not show such dependence. Here, we re-investigate three different polar arc datasets to clarify the role of the Bz component. The study shows that there exists indeed a weak correlation with negative (positive) IMF Bz for northern (southern) polar arcs and connected field-aligned currents, but the results depend strongly on the selection criteria for events that are included in the corresponding datasets.

Another unresolved issue is the direction of plasma flows along polar arcs. While most studies report of sunward plasma flow along polar arcs, there exist also observations where the plasma flow is in anti-sunward direction on at least part of the arc. With help of 73 isolated high-latitude auroral arcs, seen in DMSP measurements close to the dawn-dusk meridian, we examine the plasma flow along the arcs and in the surrounding polar cap. Our results show, a clear positive correlation exists between ionospheric plasma flow along the arc and IMF Bz but only in the sunlit hemisphere. The plasma flow along the arc is stronger and more likely to be sunward for larger IMF Bz and for a larger magnetic energy flux in the solar wind (\(v_{sw}B\)). On average, the flow along the arcs is more sunward than the average flow across the polar cap regions dawn and duskward of the arc. The polar cap flows are not dependent on the IMF strength or direction (except IMF Bz).

Abstract ID: 94504

Title: Role of High Frequency (0.1-5Hz) ULF Waves in Magnetosphere-Ionosphere Coupling: Coordinated Swarm and CARISMA Ground-based Observations

Presenter/First Author: Ian Robert Mann, University of Alberta, Edmonton, AB

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Published Material: 0 percent

Abstract Body: Using coordinated magnetic conjunctions between the CARISMA ground-based magnetometer array and the Swarm satellites we examine the role of high frequency (0.1-5 Hz) ultra-low frequency (ULF) waves in magnetosphere-ionosphere coupling. Exploiting the unique capabilities of the Swarm data, we investigate the electro-dynamical properties of electromagnetic ion cyclotron (EMIC) waves, Alfvén wave dynamics in the dayside cusp, and waves trapped in the ionospheric Alfvén resonator (IAR) on magnetosphere-ionosphere coupling. Significantly, we utilise the multi-point capabilities of subsequent close passes of Swarm A and C to investigate the spatio-temporal structure of the magnetic and electric field perturbations, investigating their relationship to field-aligned currents (FACs), Poynting flux, and the dynamical exchange of Alfvén waves between the magnetosphere and ionosphere. In addition to this scientific focus, we also investigate the impacts of these disturbances on FAC data products from the Swarm mission. Based on the results, our ultimate goal is to also investigate concepts for formulation(s) of potential new Swarm FAC data products which address the challenges associated with spatio-temporal ambiguity, including those arising from ULF waves, in the frame of the Swarm satellites.

Abstract ID: 94522

Title: Theory of the Generation of Field-Aligned Currents and Displacement Currents

Presenter/First Author: Yan Song, University of Minnesota Twin Cities, Minneapolis, MN

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Published Material: 20 percent presented at 2015 IUGG
Abstract Body: In previous theories of field-aligned current (FAC) generation (e.g., Hasegawa and Sato, 1979; Sato and Iijima, 1979; Vasyliunas, 1984), the field-aligned gradient of the FAC is determined by using the current continuity approximation, where the perpendicular current is derived from the MHD momentum equation. These theories describe only the force balance and do not describe the generation of the FAC.

We have derived the dynamical relationship between the generation of the total current $J_{\parallel \text{total}} = J_{\parallel \text{D}} + \frac{c}{4\pi} (\partial E_{\parallel} / \partial t)$ and the temporal changes and spatial gradients of magnetic and velocity shears in, for example, the auroral flux tube (e.g., Song and Lysak, 2001, 2006). Our results show that the generation of the total current is a dynamo process associated with the increase of the azimuthal magnetic flux, which is caused by the axial torque. The axial torque is produced by the Alfvénic interaction in the solar wind-magnetosphere and ionosphere coupling system.

The parallel displacement current ($J_{\parallel \text{D}} = \frac{c}{4\pi} (\partial E_{\parallel} / \partial \theta)$) describes the generation of the electric field, $E_{\parallel}$. It is $E_{\parallel}$, not $J_{\parallel}$, which accelerates charged particles. Thus it is crucial to understand the conditions, under which the displacement current $J_{\parallel \text{D}}$ and its generation become significant. We show that the $J_{\parallel \text{D}}$, i.e., the $E_{\parallel}$-generation, is closely related to low plasma density and the enhanced magnetic stress.

Continuous generation of displacement current over a fairly long time can effectively accelerate charge particles to high energy. The nonlinear interaction of incident and reflected Alfvén wave packets in inhomogeneous auroral acceleration region can produce quasi-stationary non-propagating electromagnetic plasma structures, such as Alfvénic double layers and charge holes. These structures will sustain the displacement current and can constitute powerful high energy particle accelerators, where electromagnetic energy can be efficiently converted to the particle energy.

Abstract ID: 94856

Title: Field-aligned currents in Saturn’s magnetosphere: Relationship between Subcorotation and Planetary Period Oscillation Currents

Presenter/First Author: Gregory James Hunt, University of Leicester, Leicester, LE1

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Presenter/First Author Student?: No

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Abstract Body: We present analyses of magnetic field data from the Cassini spacecraft during 2008 showing the presence of field-aligned currents in the midnight local time (LT) sector. In the southern hemisphere these currents are found to be strongly modulated in form, magnitude, and position by the phase of the southern planetary period oscillations (PPOs). In the northern hemisphere, however, we show that the currents are modulated by both the northern and southern PPO phases, thus giving the first direct evidence of inter-hemispheric PPO currents. We separate currents independent of PPO phase from the PPO-related currents, by exploiting the expected anti-symmetry of the latter with respect to PPO phase. We find that in both hemispheres the PPO-independent (subcorotation) and PPO-related currents are typically co-located and comparable in magnitude. In common with previous studies we find that in the polar regions the oscillations are hemispherically pure to within ~10% by amplitude. Both northern and southern oscillations are present on closed field lines interior to the current region, where we examine how the amplitude of the oscillations varies with latitude along the field lines. Comparing the results for the southern hemisphere to an earlier interval of data from 2006/07 in the dawn-noon LT sector also in the southern hemisphere, we find that the PPO-independent currents are essentially identical within uncertainties in the dawn-noon and midnight sectors, thus providing no explanation for the LT dependence of the Saturn kilometric radiation (SKR) emissions, which peak at ~08 h LT. The main PPO-related currents are, however, found to be slightly stronger and narrower in latitudinal width at dawn-noon than at midnight, leading to estimated precipitating electron powers, and hence emissions, that are on average a factor of ~1.3 larger at dawn-noon than at midnight, inadequate to account for the observed LT asymmetry in SKR power. Some other factor must also be involved, such as a LT asymmetry in the hot magnetospheric auroral source electron population.
SMALL-SCALE / FILAMENTARY CURRENTS

Abstract ID: 94257

Title: Small-scale magnetic field fluctuations in the low-/mid-latitude nighttime ionosphere

Presenter/First Author: Jaeheung Park, KASI Korea Astronomy and Space Science Institute, Daejeon,

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Abstract Body: The nighttime low-/mid-latitude ionosphere hosts a variety of plasma density irregularities, such as equatorial plasma bubbles (EPBs), low-latitude blobs, and medium-scale traveling ionospheric disturbances (MSTIDs). These irregularities act as sources of small-scale current systems. Plasma pressure gradient across the irregularity boundaries generates currents flowing along the boundary surface. These currents enforce or weaken background geomagnetic field strength without divergence (diamagnetic effect). On the other hand, large-scale currents flowing in the background plasma across magnetic field lines can diverge/converge at the plasma density depletion/enhancement, respectively. The current divergence results in field-aligned currents (FACs), which generates magnetic field deflections perpendicular to the background field. All these small-scale current systems make conspicuous changes in the magnetic field observed by Low-Earth-Orbit (LEO) satellites crossing the currents sheets. In this presentation we briefly review the advances since year 2000 in the field of current systems related to plasma irregularities in the nighttime low-/mid-latitude ionosphere.

Abstract ID: 94313

Title: The jxB Forces Associated With Fast Flows in Earth's Magnetosphere and Magnetosheath

Presenter/First Author: Tomas Karlsson, Royal Institute of Technology, Stockholm,

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Abstract Body: In Earth's magnetotail the bursty bulk flows (BBFs) are accelerated by the magnetic tension of newly reconnected magnetic field lines. Closer in towards Earth, the tension is balanced by an increasing magnetic pressure gradient (as well as a thermal plasma pressure gradient). These forces can be seen as the result of interaction of the local currents associated with the flow structures and the magnetic field (including both the geomagnetic field, and the currents' self-generated field). This jxB force can be evaluated by a calculation of the current density J, using multi-spacecraft measurements.

We present Cluster multi-point measurements of BBFs showing the systematic behaviour of the jxB force with downtail distance. This provides important clues to the ultimate fate of BBF's in the inner magnetosphere. We further present new results from MMS multi-point measurements of BBF events found using ExB drift velocity calculations. We report on the properties of the jxB forces of BBF events in the inner magnetosphere and near-Earth flanks.

Recently there has been an increased interest in localized flow velocity increases in the magnetosheath (here called 'magnetosheath jets'), which have some similarities to BBFs. We present first results of the jxB forces associated with such magnetosheath jets, using MMS data.
Abstract ID: 94363

Title: Current Sheets in Comet 67P/Churyumov-Gerasimenko’s Coma

Presenter/First Author: Martin Volwerk, Austrian Academy of Sciences, Vienna

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Abstract Body: A cometary coma collects the time history of the solar wind magnetic field (IMF). Around the outgassing nucleus a conducting plasma envelope will be created through ionization of the neutrals coming from the comet. Through this layer the IMF cannot freely move, but is hung-up because the magnetic diffusion speed is much slower than the solar wind speed. Changes in IMF direction will therefore be layered in this hang-up region. Rosetta, moving at slow speed through 67P/CG’s coma, measures the magnetic field and observes strong rotations of the field over short (minutes) time scales. These strong rotations have to be accompanied by local current sheets, which should display themselves in the plasma instruments. We will show examples where these rotations are indeed accompanied by an increase in the ion or electron signatures in their respective time-energy spectrograms.

Abstract ID: 94372

Title: Commonalities between Auroral Arcs and Solar Flares.

Presenter/First Author: Gerhard Haerendel, The Max Planck Institute for Extraterrestrial Physics, Garching

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Published Material: Partially presented at IPELS 2915 conference at Pitlochry
Abstract Body: The auroral energy conversion process is compared with its potential realization in the sun during flares. Emphasis is placed on the major similarities and differences between the two. In both cases the energy consumed in accelerating electrons (and ions) is derived from the release of magnetic shear stresses. Secondly, spontaneous propagation of this process is a basic property of both cases. A major difference exists with regard to the spatial and time scales. Because of the high density of the corona in comparison with that of the magnetosphere, they are extremely short. This implies the need for extremely high field-aligned current densities and that the energy conversion process would involve some kind of anomalous resistivity. The energy conversion fronts on the sun would propagate not only transversely to the shear direction but also along the magnetic field. Because of the obliqueness of the fronts, there is no return current problem for the emerging runaway electrons. The described process would most likely be realized just above the transition region and is seemingly in conflict with time-of-flight data indicating acceleration above the loop-top, albeit only for 10% of the observed hard X-ray fluxes.

Abstract ID: 94393

Title: Evolution of Bz-dips and current systems around dipolarization fronts observed by MMS

Presenter/First Author: Daniel Schmid, Space Research Institute, Austrian Academy of Sciences, Graz,

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Abstract Body: Dipolarization fronts (DF) are a key ingredient of magnetic flux transport in the magnetotail. The defining feature of DFs is the asymmetric bipolar variation of the magnetic field Z-component perpendicular to the current sheet in the tail. The sharp increase in Bz is typically preceded by a decrease, a Bz-dip, which sometimes even turns negative. We present a study on the temporal/spatial evolution of these Bz-dips and their associated current systems. We use MMS magnetotail observations during the commissioning phase when MMS has a “string-of-pearls” configuration at radial distances within 12 Re and inter-spacecraft distances of 100 km. This particular spacecraft constellation enables us to study the temporal/spatial evolution of DFs on a small scale. We characterize the DFs into two categories: earthward (Type A) and tailward (Type B) propagating DFs and examine the Bz and current change across the DF over time and/or space. The main aim of this study is to reveal common patterns of the evolution of DFs in order to better understand the magnetic flux transport in the magnetotail.

Abstract ID: 94423

Title: Resolving Spatio-Temporal Ambiguity in Field-Aligned Current Dynamics Using Swarm Multi-Spacecraft Observations

Presenter/First Author: Ivan Pakhotin, University of Alberta, Edmonton, AB

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Abstract Body: Intermediate-scale field-aligned current (FAC) systems ranging from 10 to 100 km are relatively under-investigated compared to the structure of global-scale Region 1 and 2 current systems. A common point of contention is whether the disturbances are static or Alfvénic in nature. Although some attempts were made to disentangle the spatial and temporal effects in statistical studies, most of these studies have used single spacecraft, which make such analysis difficult. Past multi-satellite observations that have been able to make the distinction have largely focused on opportunistic conjunctions.

The study conducts systematic time-domain statistical work on intermediate-scale currents using Swarm multi-spacecraft observations, separating static and dynamic effects and ultimately aiming to determine the nature of Alfvén wave coupling between the magnetosphere and ionosphere and its role in overall FAC dynamics. Using the high resolution data available from the Swarm mission, we analyse both the magnetic and electric field and related Poynting vector.
It was found that even with a 10-second orbital lag time the magnetic configuration of FAC regions changes significantly, strongly suggesting not only the importance of Alfvénic effects, but also that fundamentally field-aligned currents in geospace may be much more dynamic than currently thought.

Abstract ID: 94481

Title: Spatially Small Scale Ionospheric Currents at Mars.

Presenter/First Author: Laila Andersson, Univ Colorado, Boulder, CO

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Published Material: 0%

Abstract Body: In the lower Martian ionosphere the neutral density increases with decreasing altitude. Ions, and then electrons, decouple from the magnetic field, allowing for the closure of field aligned currents. Observations at the terminator by the MAVEN mission show that the ionosphere is filamented with narrow currents that have spatial scales of the order of the ion gyro radius. Using case studies, this work shows at which altitude the ions decouple from the magnetic field and start to move with the neutrals. The observed filed aligned currents change the conductivity as through impact ionization but cross-terminator transport also can change the conductivity. With the MAVEN mission the highly variable ionosphere at Mars can be studied.

Abstract ID: 94874

Title: Turbulence, small-scale structures, and dissipation in the solar wind

Presenter/First Author: Melvyn L. Goldstein, Space Science Institute, Baltimore, MD

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Abstract Body: The lower solar corona is a highly structured and dynamic region of the Sun's atmosphere, dominated by magnetic fields. X-ray observations of the million-degree coronal plasma reveal that solar flares and coronal mass ejections both have their origins in this region. Studies have shown that these phenomena, which require 10^25 Joules, are powered by the conversion of free magnetic energy stored in field aligned electric currents into other forms of energy. The resistive process of magnetic reconnection is central to this energy conversion. Another important, and related, aspect of these current carrying magnetic fields is the quantity known as magnetic helicity. Magnetic helicity describes the topological structure of the magnetic field. That is, how individual magnetic flux tubes are twisted and distorted and how different flux tubes are linked or braided together. Since magnetic helicity is an approximately conserved quantity, even during resistive processes, it is thought that coronal mass ejections act as a 'valve' which removes magnetic helicity from the corona. The energy required to power solar flares and coronal mass ejections cannot be supplied to the corona on the timescale of a dynamic event and so instead is thought to be built up and stored in the coronal magnetic field in the hours and day beforehand. The question then arises of which physical processes are involved in generating the field aligned currents and magnetic helicity in the corona. This talk will review both observational and modelling approaches to understanding the injection of magnetic energy and helicity into the corona. From observations of magnetic flux emergence from the solar interior into the corona and ongoing photospheric motions to the resulting coronal structures and locations where the energy is stored. The latest work to redefine the state of the art methods to estimate the amount of magnetic helicity based on photospheric injection, photospheric magnetic connectivity and volume computations will also be explored.

Abstract ID: 94873

Title: Currents and their dissipation mechanism in a solar coronal MHD model
Magnetic features, such as flux tubes, are observed to emerge from the photosphere and rise through the solar atmosphere. This causes global reconfiguration of the magnetic connectivity and hence induces currents that are eventually dissipated. How fast the reconnection may happen and if it leads to intermittent or continuous heating (nanoflares versus magnetic diffusion) is a question still under debate. Our 3D-MHD model resembles well an observed active region, featuring loops raising with a speed of about 2 km/s, which already gives hints to the real reconnection rate. The model implements magnetic-field braiding by photospheric driving of the field lines together with a realistic energy balance. While in MHD the dissipation mechanism is assumed by a simple diffusion equation, kinetic PIC simulation allow to test for this assumption well below the spatial scales resolved by MHD-processes. We try to bridge this gap with two-fold simulations: a realistic MHD corona together with a realistic electron diffusion region in a simple reconnection setup. Our MHD model supports the slow Ohmic dissipation of currents that are induced by the slow reconfiguration of the magnetic field, while our PIC model gives hints on the correctness of the assumptions we made for the MHD model.
**MEASUREMENT AND DATA ANALYSIS TECHNIQUES**

**Abstract ID:** 94359

**Title:** Multi-point Analysis of Current Structures and Applications

**Presenter/First Author:** Malcolm Wray Dunlop, STFC, Didcot,

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**Co-authors:** Junying Yang, Beihang University, Beijing, China; Stein Haaland, uib, bergen, Norway

**Published Material:** 70% journal

**Abstract Body:** The Curlometer was defined as a technique for analyzing currents from multi-spacecraft data. We review its use, primarily with the four spacecraft Cluster data, its recent developments, related techniques and new applications derived from the calculation of curl $B$ and magnetic gradients to compare estimates of the current distributions. Specifically, we explore the capability of Swarm-Cluster coordination for probing the behavior of the field aligned currents (FAC) adjacent to the ring current (RC) at medium and low orbits and show statistical analysis of the local time variation of R1/R2 FACs. The RC and connecting R2 FACs influence the geomagnetic field at low Earth orbit (LEO) and are sampled in situ by the four Cluster spacecraft. Coordination of the configuration of three Swarm spacecraft configurations with the constellation of the four Cluster spacecraft is possible; providing a set of distributed, multi-point measurements covering this region. Joint signatures of R1 and R2 FACs can be confirmed. Multi-spacecraft analysis can also access perpendicular currents associated with the FAC signatures at the Swarm locations. For context, we identify the associated auroral boundaries through application of a method to determine the FAC intensity gradients in order to interpret and resolve the R1 and R2 FACs. We also show preliminary results of an extended survey of the ring current crossings for different years, including events during non-storm and storm times, estimating the local current density, field curvature and total current; analysing the spatial extent of the ring current region.

**Title:** A review of selected data-analysis techniques for determining ionospheric electrodynamic parameters on mesoscales

**Presenter/First Author:** Heikki Vanhamäki, Finnish Meteorological Institute, Helsinki,

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**Published Material:** Material has been practically 100% published in the following 2 papers and references therein: + Vanhamäki and Amm (2011), http://www.ann-geophys.net/29/467/2011/+ Amm et al. (2015), http://dx.doi.org/10.1002/2014JA020154

**Abstract Body:** We present a review of selected data-analysis methods that are applied in studies of ionospheric electrodynamics using ground-based and space-based data sets. At present, there is no single measurement device (or even a network of devices) that can measure all ionospheric electrodynamic parameters directly and simultaneously, with good spatial and temporal resolution and coverage. Therefore data-analysis techniques are needed to combine different types of measured data and to obtain unobserved ionospheric parameters from the observed ones, possibly using some additional assumptions in the process. We concentrate on methods that are data driven and applicable to single events (not simulations or statistical models), and which can be used in mesoscale studies, where the analysis area is typically some hundreds or thousands of km across.

The primary focus of this review is in ionospheric electrodynamics, so we do not include variables like chemical composition, temperature, etc. in our discussion. We mostly concentrate on analysis techniques that have been developed to be used with data from the MIRACLE network (Magnetometers - Ionospheric Radars - All-sky Cameras Large Experiment) situated in Northern Europe, but also some techniques developed for satellite observations, such as CHAMP and Swarm, are discussed.

The full set of ionospheric electrodynamics parameters that we are interested in consist of the ionospheric horizontal electric field, height integrated Hall and Pedersen conductances, horizontal sheet current and field aligned current (FAC). Additionally, the magnetic perturbation is an important input parameter in many analysis methods. Most of the reviewed methods are used in 2-dimensional (latitude - longitude) regions of the ionosphere, but some methods have also 1-dimensional variants. In 1D analysis it is assumed that ionospheric parameters vary only in one horizontal direction (e.g. as a function of geomagnetic latitude), so input data is required along a single chain or a satellite track only.

**Abstract ID:** 94471

**Title:** Measuring currents in the solar atmosphere
Abstract Body: The brightness and morphology of coronal structures indicate that electric currents permeate the solar atmosphere, yet quantifying these currents is difficult. In this introduction to measuring currents in the atmosphere of the Sun, I will give an overview of the present state of electric current measurement near the solar surface. I will discuss a few of the challenges of remote sensing, including what it is that we actually measure and the impact of limited spatial resolution.

Published Material: As a review talk, I anticipate about 90% of the material will be taken from journal publications.

Abstract Body: Although understanding of the magnetosphere-ionosphere interaction has significantly advanced in the last thirty years, our knowledge on detailed characteristics pertaining to geomagnetic storms is still limited. One of the major challenges is to understand the basic processes associated with the development of dynamic magnetosphere-ionosphere currents, which generate large geoelectric fields on the ground. In this paper, modeled geoelectric fields, THEMIS mission and Van Allen Probes measurements are combined, for the first time, in a novel way to study drivers of geoelectric field on the ground. Results from three geomagnetic storms that occurred on 3-4 August 2010, 9 March 2012, and 17 March 2015 are presented and discussed.

Abstract Body: To calculate field-aligned current densities from a single or two-spacecraft technique, one usually assumes an infinite and planar current sheet. The method consists then in inferring the current density from one single component of the curl of magnetic field vector. We present an analytic refinement which takes into account the effect of the possible curvature of the current sheet in the determination of the field-aligned current density. We first show synthetic cases with current sheets whose curvature radii are known. We show that the results are significantly affected below some threshold. We then discuss the possibility of estimating the radius of curvature with real data from two-point measurements like the Swarm fleet can offer. We eventually apply our method to the calculation of the FAC density.
Abstract ID: 94281

Title: Intricacies of the Evolution of Heliospheric Magnetized Plasma

Presenter/First Author: Ilan Roth, University of California, Berkeley, CA

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Abstract Body: Most of the magnetic fields in space and laboratory are depicted as a bundle of strings, distorted due to stretching, bending and twisting, supported by an appropriate current system. However, numerous observations are consistent with magnetized structures which cannot be described as deformed string. The analogy between MHD and knot theory is utilized in an analysis of structure, stability and evolution of complex magnetic heliospheric flux tubes. Planar projection of a three-dimensional magnetic configuration depicts the structure as a two-dimensional diagram with crossings, to which one may assign mathematical operations leading to robust topological invariants. These invariants enrich the topological information of magnetic configurations beyond helicity. It is conjectured that the field which emerges from the solar photosphere is structured as one of simplest knot invariants — unknot or prime knot, and these flux ropes are then stretched while carried by the solar wind into the interplanetary medium. Preservation of invariants for small diffusivity and large cross section of the emerging magnetic flux makes them impervious to large scale reconnection, allowing us to predict the observed structures at 1AU as elongated prime knots. Similar structures may be observed in magnetic clouds which got disconnected from their foot-points and in ion drop-out configurations from a compact flare source in solar impulsive solar events. Observation of small scale magnetic features consistent with prime knot may indicate spatial intermittency and non-Gaussian statistics in the turbulent cascade process. First predictions for complex magnetic structures to be observed by Solar Probe Plus are presented, and the appropriate current systems are investigated.

Abstract ID: 94282

Title: Direct Reconstruction of the Magnetospheric Magnetic Field and Electric Currents from Spacecraft Data

Presenter/First Author: Varvara A. Andreeva, Saint-Petersburg State University, Saint-Petersburg, Russia

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Co-authors: Nikolai A Tsyganenko, Saint Petersburg State University, Saint Petersburg, Russia; Nikolai A Tsyganenko, Saint-Petersburg State University, Saint-Petersburg, Russia

Abstract Body: A new method is proposed to derive magnetospheric magnetic field configurations from spacecraft data. In contrast to earlier empirical models, fully or partially based on “custom-made” modules for the field sources, the new approach is free of any a priori assumptions on the spatial structure of electric currents. The external part of the geomagnetic field is represented by the sum of poloidal and toroidal terms, each expanded into series of radial basis functions (RBF) with their nodes regularly distributed over the 3D modeling domain. The feasibility of the approach has been verified by reconstructing the inner and high-latitude magnetospheric field within geocentric distances up to 12Re on the basis of magnetometer data of Geotail, Polar, Cluster, Themis, and Van Allen space probes, taken during 1995-2015. Four characteristic states of the magnetosphere before and during a disturbance have been modeled: a quiet pre-storm period, storm deepening phase with progressively decreasing Sym-H index, the storm maximum around the negative peak of the Sym-H, and the recovery phase. Fitting the RBF model to data faithfully resolved contributions to the total magnetic field from all principal sources, including the westward and eastward ring current, the tail current, diamagnetic currents associated with the polar cusps, and the large-scale effect of the field-aligned currents. For the main phase conditions, the model field reveals a strong dawn-dusk asymmetry of the low-latitude magnetic depression, extending to low altitudes and partly spreading sunward from the terminator plane in the dusk sector. It is also demonstrated that large tilt angles of the Earth’s dipole with respect to the terminator plane result in largely different magnitudes and spatial configurations of the diamagnetic depression in the northern and southern cusps. Varying the spatial extent and coverage density of the RBF nodes allows one to adjust the resolution and focus the modeling at specific regions of interest of the geospace, which opens an interesting possibility to develop the proposed method into a powerful tool for data-based studies of the magnetospheric currents.

Abstract ID: 94384

Title: Modeling Magnetospheric Current Systems
Planetary environments provide compelling natural laboratories for exploring and quantifying a spectrum of dynamic magnetospheric processes. Current systems play an important role in coupling various regions of the magnetosphere, and can produce magnetic signatures that reveal details of local plasma interactions. This presentation will provide an overview of various methods developed for modeling magnetospheric currents throughout the solar system. Specifically, I will explore the assumptions implemented in these models as well as the methods used for comparing and validating against observable quantities. The focus will be split between models describing large-scale magnetospheric currents and those exploring smaller-scaled moon-magnetosphere systems, where recent observations of asymmetric neutral plumes and charged dust have forced us to re-examine how we model the currents in these small but complex environments.

Title: The Simulation of the Ionospheric Current System and Its Impact on the Earth’s Magnetic Field

For this study, we perform the modelling of the dynamic ionospheric current system. Those simulations are done with an improved version of the first-principle, time-dependent, and fully self-consistent numerical global Upper Atmosphere Model (UAM-P). This model describes the thermosphere, ionosphere, plasmasphere and inner magnetosphere as well as the electrodynamics of the coupled Magnetosphere – Ionosphere – Thermosphere (MIT) system.

Additionally, we calculate the contribution of the ionospheric currents to the Earth’s magnetic field. For this purpose, we obtain the additional magnetic field from the system of the ionospheric currents calculated with the UAM-P model. The magnetic field generated by the ionospheric currents is calculated using the Biot-Savart law. The ionospheric impact on the magnetic field is significant at dayside and high-latitude regions, where maximum values of these currents occur. The additional magnetic field of ionospheric origin depends on the geomagnetic conditions and has significant seasonal and UT variations.
Abstract Body: While magnetohydrodynamics (MHD) is a reasonable first order, self-consistent representation of the physics of the magnetosphere, there are regions and processes where it is inadequate. One example is in the ring current region where energy dependent non-MHD drifts, such as gradient and curvature drifts, become important. This presentation will describe the basic assumptions that go into the Rice Convection Model (RCM), which also includes the self-consistent coupling to the ionosphere through Birkeland currents. Extensions to the RCM to include a force balanced magnetic field (RCM-E) and coupling to Global MHD will also be described. Finally, our approach to including physics not represented in the original RCM framework will be described. One example of this is representing transient bursts of rapid transport, termed “bursty bulk flows (BBFS)” or “bubbles” that have important consequences on the structure and dynamics of electric and magnetic fields in the inner magnetosphere.

Abstract ID: 94428

Title: Current Systems at Moons

Presenter/First Author: Mats Holmstrom, Swedish Inst Space Physics, Kiruna,

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Presenter/First Author Student?: No

Abstract Body: We review the modeling and modeling results for current systems at different moons. We focus on the Moon, but also discuss other moons in the solar system, e.g., Rhea and Callisto. Currents can be present

- in the interior,
- in the ionosphere, or
- in the surrounding plasma.

The importance of the currents in these different regions will be different for different objects. For the Moon, the currents in the interior and in the surrounding plasma are most important since the ionosphere is so tenuous. For other moons like Callisto, all three current systems are important.

The modeling of current systems present some numerical challenges. For particle models, the magnetic fields are often noisy. Since currents are computed by derivatives of the magnetic fields, the computed currents will not be smooth. We also discuss advantages and disadvantages of computational methods that use currents instead of magnetic fields as primary variables. The modeling of interior currents implies that a magnetic diffusion equation has to be solved. In the algorithm this region has to be coupled to the external plasma region. This can also introduce a large range of timescales. For moons without a significant ionosphere there is also the numerical challenge of how to handle the low density regions in the wake of the moon.

Abstract ID: 94464

Title: About a quasi-adiabatic motion of charged particles in heliospheric current sheet

Presenter/First Author: Helmi V Malova, Space Research Institute RAS, Moscow,

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Presenter/First Author Student?: No

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Abstract Body: The work is devoted to the investigation of both the structure of the heliospheric current sheet (HCS) and mechanisms of its formation. Self-consistent hybrid model of the HCS is developed, where ion dynamics has been described in a frame of quasi-adiabatic dynamics, while the electron motion is considered as a fluid one. HCS is found to be a relatively thin multiscale plasma configuration which is embedded inside much thicker plasma sheet. It is shown that HCS can be supported by the current of demagnetized protons on open quasi-adiabatic orbits as well as electron drift currents. The possibility to apply the model results to interpretation of experimental observations is proposed.

Abstract ID: 94476

Title: Earth’s Auroral Acceleration Region: Comparison of Cluster data and Vlasov model results
Effect of ionospheric current system geometry on local surface EM observation - a theoretical model

Presenter/First Author: Istvan Lemperger, MTA GGKI/GGRI of HAS, Sopron

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Abstract Body: The primary natural source of the ULF range surface geomagnetic field variations are the ionospheric-magnetospheric currents. Subsurface electric (telluric) currents arise by means of the induction effect, resulting secondary magnetic field at the surface. The total surface geomagnetic field is superposition of the primary and the secondary components. The surface electromagnetic impedance is computed as the complex ratio of the telluric and total geomagnetic field at certain location of surface observation. The modulus and phase of the impedance tensor elements are dominantly determined by the spatial distribution of subsurface electric conductivity. However, the geometry of the source current systems might have significant indication on the impedance tensor at certain frequencies. In a theoretical approach, analytic computation of surface electromagnetic impedance has been performed in case of a general source current system geometry. Realistic ionospheric current system model and horizontal layered media have been assumed. The applied current system model is a temporally and spatially varying amplitude, 2D current density vector field in the height of 120km. The influence of the following parameters has been considered:

- the parallel (with the current-density vector) extent of the source current system,
- the perpendicular (to the current-density vector) extent of the source current system,
- the spatial variability of the source
- and the frequency.

above a physically realistic domain of the geometrical parameter-space. The presentation provides a brief summary of the results of the analytic calculations.

Abstract ID: 94493

Title: Assessment of inductive electric fields contribution to the overall particle energization in the terrestrial magnetosphere
The terrestrial magnetosphere has the capability to rapidly accelerate charged particles up to very high energies over relatively short times and distances. These energetic particles are injected from the magnetotail into the inner magnetosphere through two primary mechanisms. One transport method is the potential-driven convection during periods of southward IMF, which allows part of the dawn-to-dusk solar wind electric field to effectively map down to the polar ionosphere. The second transport process involves a sudden reconfiguration of the magnetic field and the creation of transient induced electric fields.

However, it is not possible to distinguish the two terms by only measuring the electric field. Assessing the relative contribution of potential versus inductive electric fields at the energization of the hot ion population in the inner magnetosphere is only possible by thorough examination of the time varying magnetic field and current systems using global modeling of the entire system.

We developed a new method to calculate the induced electric field in the entire magnetosphere domain. This approach removes the need to trace independent field lines and lifts the assumption that the magnetic field lines can be treated as frozen in a stationary ionosphere. We quantify the relative contributions of potential and inductive electric fields at driving plasma sheet ions into the inner magnetosphere during disturbed conditions. The consequence of these injections on the distortion of the near-Earth magnetic field and current systems have been rarely separated in order to determine their relative effectiveness from a global perspective.

Abstract ID: 94537

Title: Current and Current Sheets in the Solar Corona and their Relation to Solar Eruptions

Presenter/First Author: Joerg Buechner, Max Planck Institute for Solar System Research, Katlenburg-Lindau,
Abstract Body: Solar eruptions usually start as an instability of flux ropes in the corona. Magnetic flux ropes are supposed to be related to currents in the corona. Unfortunately, coronal currents cannot be measured directly. They can be approximately obtained, however, by numerical simulations based on observations of photospheric magnetic fields. We present current simulation results revealing the currents in coronal flux ropes prior and at the moment of an eruption. It appears that the creation of toroidal and poloidal current channels play a crucial role in creating the magnetic forces causing a global flux rope instability behind a Solar eruption. These results are compared and validated by the results of current laboratory eruption experiments [Myers et al., Nature, Dec 2015].

Abstract ID: 94301

Title: Magnetic Flux For The Substorm Current System And Dipolarization Fronts

Presenter/First Author: Anthony Lui, The Johns Hopkins Univ, Laurel, MD

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Abstract Body: Recent emphasis on dipolarization fronts (DFs) has led to the impression DFs play a significant role in bringing magnetic flux to the inner magnetosphere for the substorm current system. In this work, we investigate the amount of magnetic flux transport associated with DFs by examining the frozen-in field line condition (FIC) for previously reported DF events. A study of 18 DF cases shows that the FIC does not hold for 17 cases when the ratio of \(|E_x + (V \times B)_i|/(V \times B)_i|\) exceeds 0.5, i.e., the mismatch of \(E_x\) and \(−(V \times B)_i\) exceeds 50%. Furthermore, the peak magnetic flux transport rate for DFs in which FIC holds is found to be in the range of \(8–42\ kWb/s/R_{Earth}\) while the accumulated flux transport within the DF intervals to be \(0.1–2.8\ MWb/R_{Earth}\). Assuming a dawn-dusk dimension of \(3\ R_{Earth}\) for a DF, the accumulated magnetic flux transport is \(0.3–8\ MWb\), which amounts to \(0.1–2.2\%\) of what is needed to account for magnetic flux increase in the near-Earth dipolarization for the substorm current system. This result casts doubt on the idea that DFs play a significant role in substorm dipolarization and the substorm current system.

Abstract ID: 94325

Title: Simple Electric Currents with Tangled Magnetic Fields

Presenter: Anastasia Lukashenko, Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow,

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Abstract Body: We consider analytically and numerically the geometry and topology of magnetic field lines, tubes and surfaces for the simple electric current systems exemplified by two ring currents. Local and global properties demonstrate ample and not expected diversity with regular and irregular field lines when the symmetry is not high. Most of field lines usually is not closed, but open and irregular with both ends lost in the finite volume. The manifold of regular closed field lines is continuum only in the case of a sufficiently high symmetry. Otherwise, this manifold is countable as in the classical case of I. Tamm (linear wire with a planar concentric ring current) representing axially symmetric imbedded tori with rational and irrational lines. Deformed magnetic surfaces and tubes do not exist globally as a rule in such cases and can be only local characteristics contrary to existing textbook cartoons. It is due to absence of independent integrals. Algebraic simplicity of formulae for the electric currents does not guarantee per se the simplicity of the field line geometry. The overall situation is usually similar to dense Cantor sets of rational and irrational numbers. We demonstrate this thesis by our numerical calculations. Hidden symmetry arguments and separation of variables discussed for the possible finding of integrals. New classification of zero points for potential magnetic fields developed using harmonic expansions up to the second and higher orders in the distance. The results are useful.
in the magnetic reconnection theory for different approximations and their validations in space and laboratory plasmas such as tokomaks etc. The conclusion that magnetic field chaos can naturally arise with simple electric current configurations.

Abstrat ID: 94328

Title: Electric Currents and Twisted Plasma Jets in the Fermi Bubbles

Presenter/First Author: Igor S. Veselovsky, Space Research Institute (IK) RAS, Moscow,

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Presenter/First Author Student?: No

Published Material: The material not published previously.

Abstract Body: Electric currents anticipated by analogy with the solar and heliospheric case. Quasisteady and transient effective plasma and current systems are both conceivable. Fermi Bubbles can be remnants of an eruption from the Milky Way Galaxy central region. If so, the dense plasma core inside the magnetic cloud can remain or not remain in analogy with known eruptive prominence – CME – flare energy releases on the Sun. The remarkable symmetry of twins against the axis indicates on simultaneous origin of Fermi Bubbles. Simple illustrative model of the central explosion with shocks in the pre-existing point dipole magnetic field with the thin equatorial current sheet presented. The physics of phenomena can involve gravity, electromagnetic, plasma and inertia forces as well as known and unknown nuclear interactions. Dimensionless scaling between them is not quite clear and needs more data. Independent of this dynamical uncertainty and richness, one may expect to find the twisted plasma jets inside both Fermi Bubbles just because of the overall geometry considerations. Left-handed or right-handed orientations will indicate the azimuthal asymmetry against the axis. Pinch or firehose instability details not known with regulating plasma beta and Alfvén Mach parameters. The number of turns expected to be small, ~1 for the relativistic expansion. The bar in the galaxy considered as the projection of the thin plasma sheet on the plane of the sky. Spiral arms probably originate from the combination of rotation and radial expansion as in the solar wind case beyond the source surface and the Alfvén surface. We conclude that the considered analogy with the solar corona is useful but limited.

Abstrat ID: 94361

Title: Generator and load regions in the magnetotail

Presenter/First Author: Maria Hamrin, Umeå Univ, Umea,

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Presenter/First Author Student?: No

Published Material: This is an invited talk on the work I have done together with collaborators on energy conversions issues in the Earth’s magnetotail. Hence all material have been published previously in several articles in Annales Geophysicae and in Journal of Geophysical Research

Abstract Body: Energy conversion processes play an important role for the dynamics of the Earth’s magnetotail. They can be probed through the power density, E·J, where E and J are the electric field and the current density, respectively. In a load process, for example magnetic reconnection and auroral acceleration, electromagnetic energy is converted into kinetic energy and E·J>0. In a generator (dynamo) process, such as the deceleration of fast magnetotail flows, energy is transferred in the opposite direction and E·J<0. Multispacecraft missions such as Cluster and MMS are favorable for observational investigations of energy conversion using E·J, since at least four simultaneous magnetic field measurements are needed for estimating the full vector J. By using Cluster E·J data from 2001-2004 we have investigated the statistical properties of plasma sheet energy conversion regions, and the role of the plasma sheet in channeling solar wind power to the ionosphere. Studying a fortunate interval of conjugated Cluster-FAST data, we have been able to associate the auroral acceleration observed at lower FAST altitudes with possible auroral generator regions at higher Cluster altitudes. In addition, in our investigations, we have used E·J to study both plasma acceleration and deceleration processes. In particular, we have found that E·J can be used as a tool for identifying possible magnetic reconnection events from large sets of data, e.g., from the Cluster and MMS missions.

Abstract ID: 94394

Title: Magnetic Fields and Currents at Mars and Venus.

Presenter/First Author: Edward Dubinin, Max-Planck-Institute for Solar System Research, Goettingen,

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Presenter/First Author Student?: No
Abstract Body: Venus and Mars have no a global intrinsic magnetic field and solar wind interacts directly with their ionospheres inducing draping magnetospheres. Due to additional currents related to the Hall currents and a different dynamics of different ion species a draping on both planets occurs not symmetrical relative to the direction of the solar wind motional electric field. During solar maximum conditions, the ionosphere of Venus is almost decoupled from solar wind by the magnetic barrier formed by pile-up of the IMF. It is almost unmagnetized except of small-scale magnetic flux ropes. During solar minimum conditions on Venus and most of time on Mars, large-scale magnetic fields are observed deeply in the planetary ionospheres (magnetized ionospheres) raising a question about the origin of these fields. The problem is intimately related to the issue of electric current system and its closure. Mars Express, Venus Express and MAVEN spacecraft have provided us a wealth of in-situ observations of characteristics of induced magnetospheres of Mars and Venus at low altitudes during solar minimum conditions. Although solar wind is terminated at a certain distance from the planets by the magnetic barrier, the thermal ionospheric pressure is not able to balance there the external pressure and the upper ionosphere becomes to be driven into a slow convective motion implying an absence of a static equilibrium in the magnetic barrier. Such a flow carries the magnetic field and the ionosphere becomes magnetized. A static balance is maintained at lower altitudes (≤ 200 km) where the collisional drag force arising from a relative motion between plasma and neutrals balances the external forces. At such altitudes the Hall currents become dominant and produce very asymmetrical distribution of the ionospheric magnetic fields. Structure of the near planet tail also occurs very asymmetrical due to these currents and asymmetrical motion of different ion species. The observations also show that the electric currents which support the magnetic field configuration in the tail are mainly the inertia currents rather than the pressure gradient currents. The 3-D hybrid simulations of the solar wind interaction with Mars and Venus provide us an additional powerful tool for a better insight into the current system of the induced magnetospheres.
enhancements in geomagnetic fields can be extremely localized, in both time and space, and difficult to predict in any deterministic manner. Probabilistic predictions are possible given accurate data distributions, but a scarcity of geomagnetic observing systems makes it difficult to generate spatially continuous “hazard maps”. Global geospace models can help fill in the gaps, but only if they generate physically realistic electric current distributions. If this holds, synthetic data distributions can be generated for any location in the computational domain. The Lyon-Fedder-Mobarry (LFM) model was used to simulate the Whole Heliosphere Interval (WHI), one full rotation of the sun with two high-speed solar wind intervals, at various grid resolutions. We discuss the results in terms of probabilistic predictions of geomagnetic disturbance, and related projects for mapping storm-time geomagnetic activity.

Abstract ID: 94412

Title: Simulating the three-dimensional ionospheric current system

Presenter/First Author: Astrid I Maute, NCAR/HAO, Boulder, CO

Presenter/First Author Email: maute@ucar.edu

Co-authors: Arthur D Richmond, National Center for Atmospheric Research, Boulder, CO; Arthur D Richmond, NCAR/HAO, Boulder, CO; Arthur D Richmond, NCAR-High Alt Observatory, Boulder, CO; Gang Lu, National Center for Atmospheric Research, Boulder, CO

Published Material: 10% at AGU Fall meeting San Franisco, December 2015.

Abstract Body: Ionospheric electric fields and currents are driven by collisional interaction between thermospheric winds and ions, by magnetospherically driven ion convection and field-aligned currents at high latitudes, by gravitational and pressure-gradient forces on the ionospheric plasma, and by weak currents from the lower atmosphere. For time scales longer than a few minutes the electric field is electrostatic. It is also a reasonable assumption that the electric potential is nearly constant along geomagnetic-field lines. Therefore the electric field can be represented in two dimensions in a coordinate system aligned with the geomagnetic field. The current density, however, which depends also on the conductivity distribution, varies in all three dimensions.

We are developing a model of ionospheric electrodynamics that takes into account the wind dynamo, the magnetospheric field-aligned current, and gravitational and pressure gradient forces to calculate the three-dimensional structure of currents and their associated magnetic perturbation fields at the Earth’s surface and at Low Earth Orbit (LEO) satellite altitudes.

We will use this model to examine the effects of the different sources on the 3-dimensional currents and their associated magnetic perturbations. An accurate description of the 3D ionospheric currents is critically important to interpreting satellite observations at LEO height as they are affected by the various atmospheric forces all together. In this presentation we will introduce the new capabilities of calculating the 3-dimensional ionospheric current and magnetic perturbations. With selected examples we will illustrate the currents and magnetic perturbations produced by the neutral wind during quiescent and geomagnetic active times, and those produced by gravity and plasma pressure-gradient forces on the plasma. We will discuss possible improvements in the modelling of ionospheric currents driven by magnetospheric sources.

Abstract ID: 94415

Title: Pioneers of Electric Currents in Geospace

Presenter/First Author: Asgeir Brekke, University of Tromsø, The Arctic University of Norway, Tromsø,

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Presenter/First Author Student?: No
Abstract Body: Abstract

This presentation will give an overview of the development of our understanding of the electric currents in geospace. Traditionally it has been accepted that the German British scientist Alfred Lothar Schuster in 1908 was the first to introduce a conducting layer in the upper atmosphere in order to explain the tidal motions of the Earth’s magnetic field by electric currents on a global scale. Since then the technique to invert magnetic field data to patterns of global current systems have been greatly improved by the introduction of models of the height integrated conductivities.

The auroral zone ionosphere plays an important role in the electrodynamic coupling between geospace and the upper polar atmosphere. The Norwegian Physicist Kristian Birkeland introduced in 1908 a theory where he proposed that charged particle rays from the Sun, when approaching the Earth, are forced by the magnetic field to carry currents along the field lines toward the poles, and that these currents are closed in a horizontal current along the auroral arc. This theory was not well appreciated by his contemporary colleagues and was not fully accepted until the Space Age when satellite observations confirmed the presence of field aligned currents at high latitudes.

Based on incoherent scatter radar experiments during the last 35 years, it has been possible to show that by combining observed electric fields and winds together with the height integrated conductivities, the magnetic fluctuations simultaneously observed on ground are the result of the height integrated currents in the ionosphere.
Abstract Body: Mass and momentum loading due to ionization and due to charge exchange between ions and neutrals within flowing, magnetized plasmas are generally referred to as “pickup”. Pickup plays an important role in the interaction of many planetary bodies with their surrounding plasmas, e.g., at the moons of Jupiter. Due to pickup the plasma flow can be strongly modified with associated strong magnetic fields perturbations. The magnetic field perturbations generated by pickup are frequently associated with so called “pickup currents”. In our presentation we will review physics and implications of the pickup process and discuss its related electric currents. Based on Vasyliūnas 2006 we will also critically assess a picture introduced by Goertz (1980) that the displacements of ions and electrons as a result of their acceleration and gyro-motions under the action of a motional electric field generates pickup currents directly responsible for the magnetic field and flow perturbations.
the growth and expansion phase are discussed. We conclude that the envelope of the magnetic disturbances which we typically refer to as an intense magnetic substorm is the result of a group or sequence of more intense and more frequent NFTEs.

Abstract ID: 94454

Title: Electric Fields and Field-Aligned Currents Associated with Aurora. The Heritage of Hannes Alfvén

Presenter/First Author: Goran Tage Marklund, Royal Inst Technology, KTH/EES, Stockholm,

Presenter/First Author Email: goran.marklund@ee.kth.se


Abstract Body: For the discovery of magneto-hydrodynamic waves, published in Nature 1942, and for other important fundamental contributions to plasma physics, Professor Hannes Alfvén was awarded the Nobel Prize in Physics 1970. He was first to propose that electric fields with a component aligned with the Earth’s magnetic field (1958) produced aurora. The first in situ observations of accelerated particles producing aurora were presented by McIlwain (1960). Alfvén argued strongly for the importance of measuring electric fields in space plasmas, which initiated the development of the double probe technique, first presented by his graduate student Ulf Fahleson in a PhD dissertation 1967 at KTH. The technique was subject to much further development in close collaboration with Professor Forrest Mozer, University of California, Berkeley. It has been used to measure electric fields on numerous rocket and satellite missions, such as the NASA missions S3-3, Dynamics Explorer, Polar, FAST, and Themis, the Viking and Freja satellites, and the ESA Cluster mission. From these and other missions, there are today overwhelming experimental evidence that quasi-static parallel electric fields play a key role to accelerate auroral particles. In the mid 90’s, diverging electric field structures and downward electric fields were discovered in the downward current region by the Freja satellite. Another, closely related, and very efficient acceleration process is by time-varying parallel electric fields of kinetic and inertial Alfvén waves, responsible for producing solar boundary intensifications and other types of dynamic aurora. With the Cluster satellite launches 2000, multi-point observations on auroral field lines became a reality and later direct crossings of the acceleration region allowed multi-probing of this key region, the first of its kind. Results are presented from event and statistical studies of Cluster data, addressing various open issues such as: the relative role by quasi-static and time-varying electric fields for producing aurora; the altitude distribution of the parallel electric field and potential; their temporal evolution; the structure and stability of the acceleration region; the auroral density cavity and its distribution in altitude with respect to the AAR; the field-aligned current closure in surges.

Abstract ID: 94466

Title: EMVIM: An empirical model for the magnetic field configuration near Venus

Presenter/First Author: Maosheng He, Jacobs University Bremen, Bremen,

Presenter/First Author Email: m.he@jacobs-university.de

Published Material: The model we present here is under review in JGR space physics. Manuscript ID: 2015JA022049R

Abstract Body: More than 2000 orbits of Venus Express of magnetic field measurements are condensed into EMVIM, an empirical model to quantify the magnetic configuration in the Venusian magnetosphere at low altitude (<500km) as a function of the upstream solar wind magnetic field (IMF components) and solar activity index F107. Empirical Orthogonal Function (EOF) analysis is used to decompose the data and to separate different dynamics on different basis function. The most important basis function represents the magnetic draping configuration of the IMFz component, while the second important one represents the draping of the IMFy component. Solar wind-magnetosphere interactions are quantified through regression analysis of EOF amplitudes and solar wind predictor variables. Combining the basis function with regression coefficients results in a model with a determination coefficient R2 of 0.29. As an application example, the model is used to quantify the density of the cross-tail current sheet as [see below] revealing the
EMVIM: An empirical model for the magnetic field configuration near Venus

Maorbing He1,*, Joachim Vogt1, Tiehong Zhang2, Zhaojin Rong2

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More than 2000 orbits of Venus Express of magnetic field measurements are condensed into EMVIM, an empirical model to quantify the magnetic configuration in the Venetian magnetosphere at low altitude (<500 km) as a function of the upstream solar wind magnetic field (IMF components) and solar activity index F10.7. Empirical Orthogonal Function (EOF) analysis is used to decompose the data and to separate different dynamics on different basis function. The most important basis function represents the magnetic draping configuration of the IMF component, while the second important one represents the draping of the IMF component. Solar wind-magnetosphere interactions are quantified through regression analysis of EOF amplitudes and solar wind predictor variables. Combining the basis function with regression coefficients results in a model with a determination coefficient $R^2$ of 0.29. As an application example, the model is used to quantify the density of the cross-tail current sheet as

$$J_z = \frac{3.75 \cdot IMF_y - 0.0190 \cdot IMF_y \cdot F107 - 0.00182 \cdot F107^2 + 13.6}{nT \cdot sfu - nT \cdot sfu^2} \text{ A} \cdot \text{km}^{-2}$$

revealing the intensity decreases with increasing solar activity.

Abstract ID: 94491

Title: Induced Currents in Subsurface Oceans at the Uranian Satellites Oberon and Titania

Presenter/First Author: Christopher Stephen Arridge, University College London, London,

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Presenter/First Author Student?: No

Co-authors: Joseph WB Eggington, Lancaster University, Lancaster, United Kingdom

Published Material: None.

Abstract Body: In the jovian system, the tilted magnetic dipole of Jupiter generates time-variable fields near the moons at their synodic rotation periods. The subsurface ocean at Jupiter’s moon Europa was detected from the magnetic signature of currents induced in the conducting ocean by this variable external field. In the uranian system, episodes of intense tidal heating is expected to have produced internal melting in some of the icy natural satellites. The two largest satellites, Titania and Oberon, may still have liquid water oceans beneath their outer ice shells. The magnetic field of Uranus is more strongly tilted than that of Jupiter and so we might expect a clear induction signal from these oceans.

In this poster we use published models for the interiors of Titania and Oberon to model the induction signal from subsurface oceans at these satellites. From this modelling we explore the measurement requirements to detect these oceans from a future orbiting spacecraft. We also consider the nature of the magnetospheric interaction with the moons and how associated current systems would affect the signal from the induced currents.
Abstract ID: 94497

Title: Middle-Latitude Ionospheric Irregularities and Ring Current Expansion during Geomagnetic Storms

Presenter/First Author: Xiaoqing Pi, Jet Propulsion Laboratory, Pasadena, CA
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Presenter/First Author Student?: No
Published Material: 10% at 2015 AGU Fall meeting.

Abstract Body: This presentation will show distinguished pictures of middle-latitude ionospheric irregularities and its relationship with ring current enhancement and expansion during geomagnetic storms. Nominally ionospheric irregularities can occur at low latitudes after sunset during certain seasons. Under disturbed space weather perturbations, spatial and temporal variations of the plasma convection and dynamics of auroral arcs can drive development of ionospheric irregularities in the polar region. Such irregularities can cause scintillation and degradation of L-band GNSS radio signals and affect satellite navigation systems. To study the irregularities, snapshot Global Maps of Ionospheric Irregularities and Scintillation (GMIIS) have been generated at the Jet Propulsion Laboratory using GPS data collected from global GNSS networks. Analysis of GMIIS shows that the irregularities can expand down to sub-auroral and middle latitudes (well below 50 degree dip latitude) during certain storms. The affected middle-latitude region can be a major part of the U.S. continent during some events. Such events are distinguishably different from the well-established global picture in which ionospheric irregularities and scintillation are predominately occur at low and high latitudes. It is also discovered that all major events examined so far are associated with significant ring current enhancement before the recovery phase of the storms. The relationship between the irregularity and ring current activities indicates that the ring current expansion into the plasmasphere is likely responsible for the middle-latitude irregularity phenomenon. Under this condition the plasma convection driven by the magnetospheric processes penetrates into middle latitudes, and its variations can cause ionospheric irregularities as seen in GPS data. This presentation will show major events of middle-latitude irregularities and its relationship with the ring current. The responsible mechanisms will be discussed. The presentation will add the middle-latitude ionospheric irregularities and scintillation into the global picture of ionospheric irregularity and scintillation distribution.

Abstract ID: 94501

Title: How much curl-free Hall current flows out to the magnetosphere as field-aligned current from Cowling channel?

Presenter/First Author: Akimasa Yoshikawa, Kyushu University, Fukuoka,
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Presenter/First Author Student?: No

Published Material: How much curl-free Hall current flows out to the magnetosphere as field-aligned current from Cowling channel? The Cowling channel is a generic name of a current system flowing inside a high conductivity band, in which a secondary polarization electric field is excited via preventing a divergence part of Hall current to flow out to the magnetosphere as the field-aligned current (FAC). Hereafter as stated by Amm et al., [2011], we refer to the notion of Cowling effect and Cowling channel whenever an electric field (perpendicular to B and) tangential to horizontal gradients of conductances occurs and a secondary (polarization) electric field builds up. Since the primary and secondary electric field point to different directions, the total electric field E (thus, the ionospheric convection) is different from primary electric field in the region where the primary Hall current is confined in the ionosphere. Therefore, from viewpoint of the Magnetosphere- Ionosphere (M-I) coupling, important questions are: How does the Cowling effect change the ionospheric flow pattern from the magnetospheric convection mapped onto the ionosphere as a result of charge separation at the conductivity edge, and how can such deformed convection and the resulting field-aligned current (FAC), which has ionospheric origin, feed back to the magnetosphere.

Abstract Body: The Cowling channel is a generic name of a current system flowing inside a high conductivity band, in which a secondary polarization electric field is excited via preventing a divergence part of Hall current to flow out to the magnetosphere as the field-aligned current (FAC). Hereafter as stated by Amm et al., [2011], we refer to the notion of Cowling effect and Cowling channel whenever an electric field tangential to horizontal gradients of conductances occurs and a secondary (polarization) electric field builds up. Since the primary and secondary electric field point to different directions, the total electric field E is different from primary electric field in the region where the primary Hall current is confined in the ionosphere. Therefore, from viewpoint of the Magnetosphere- Ionosphere (M-I) coupling, important questions are: How does the Cowling effect change the ionospheric flow pattern from the magnetospheric convection mapped onto the ionosphere as a result of charge separation at the conductivity edge, and how can such deformed convection and the resulting field-aligned current (FAC), which has ionospheric origin, feed back to the magnetosphere.
To quantify the Cowling effect, we need to know the relative strength of the polarization field and to what extent it cancels (closes) the primary Hall current. This problem is complementary to the question [Amm et al., 2011; Fujii et al., 2011], how much curl-free Hall current flows out to the magnetosphere as FAC.

On the basis of electron and ion continuity equations with their mobility inside ionospheric E-region, we reformulate current closure process between FAC and ionospheric divergent current in a quasi-steady state. A divergence free condition of 3-dimensional electron-flow and 2-dimensional ion-flow results in very fundamental pictures: (1) FAC always closes to the Hall current carried by electrons, (2) Pedersen current divergence always balances to the divergence of Hall current carried by ions and secondary polarization electric field is produced by this process. This scenario is universal and gives significant restriction to the closure condition between ionospheric current and FACs.

In this presentation, we will review the outstanding problem relating to Cowling channel and discuss about their role in a Magnetosphere-Ionosphere coupling.

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**Abstract ID:** 94503

**Title:** Multi-satellite Observations of Long-lasting Poloidal Pc 4 Pulsations in the Dayside Magnetosphere

**Presenter/First Author:** Galina Ivanovna Korotova, University of Maryland College Park, College Park, MD

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**Presenter/First Author Student?:** No

**Co-authors:** David G Sibeck, NASA Goddard Space Flight Center, Greenbelt, MD; David G Sibeck, NASA GSFC, Greenbelt, MD; David G Sibeck, NASA/GSFC, Greenbelt, MD; Mark J. Engebretson, Augsburg College, Minneapolis, MN

**Published Material:** AGU 2014 40%

**Abstract Body:** We use magnetic field and plasma observations from Van Allen Probes and THEMIS spacecraft to study spatial and temporal characteristics of long-lasting poloidal Pc4 pulsations in the dayside magnetosphere. They were observed after the main phase of the strong storm during low geomagnetic activity. The most striking feature of the Pc4 pulsations was their occurrence at similar locations on three of four successive orbits of Van Allen Probes nine hours apart. The pulsations were generated during various interplanetary conditions and the solar wind parameters do not seem control the occurrences of the pulsations. We studied latitudinal nodal structure of the pulsations. We tested possible mechanisms for their generation.

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**Abstract ID:** 94527

**Title:** Swarm - the European Space Agency’s constellation mission: Mapping Earth’s external field

**Presenter/First Author:** Rune Floberghagen, European Space Agency, Frascati,

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**Presenter/First Author Student?:** No

**Abstract Body:**

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**Abstract ID:** 94534

**Title:** Current systems in the Core of Magnetic Reconnection

**Presenter/First Author:** Michael Hesse, Space Weather Laborato, Greenbelt, MD

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**Presenter/First Author Student?:** No

**Co-authors:** Yi-Hsin Liu, NASA Goddard Space Flight Center, Greenbelt, MD; Yi-Hsin Liu, Los Alamos National Lab, Los Alamos, NM; Li-Jen Chen, University of Maryland College Park, College Park, MD; Li-Jen Chen, NASA Goddard Space Flight Center, Greenbelt, MD; Li-Jen Chen, University of New Hampshire, Durham, NH; Li-Jen Chen, Univ of New Hampshire, Durham, NH; James L Burch, Southwest Research Institute, San Antonio, TX; James L Burch, Southwest Research Institute San Antonio, San Antonio, TX; Joachim Birn, Los Alamos National Laboratory, Los Alamos, NM; Joachim Birn, Space Science Institute, Los Alamos, NM
Abstract Body: Magnetic reconnection is arguably the most fundamental transport and energy conversion process in plasmas. In plasmas, where classical collision frequencies are sufficiently low—such as occur in a large variety of space- and solar environments, magnetic reconnection has to be based on kinetic processes. Kinetic aspects start with those enabling the electric field in the core of the reconnection diffusion region, and continue to various particle acceleration processes, which, among other features, enable the outflow jets. The reconnection electric field serves, as one of its key functions, to maintain currents necessary for the field reversal, and electron outflow jets are another key aspect of the complex current structure in the vicinity of the electron diffusion region. This presentation will provide an overview of modern research addressing key kinetic aspects of reconnection. The focus will be on the structure of currents in the inner core of magnetic reconnection based on both theoretical analyses and comparisons to observations from the Magnetospheric Multiscale (MMS) Mission.

Abstract ID: 94536

Title: Planetary induction currents and their effects on magnetospheres

Presenter/First Author: Frank J Crary, University of Colorado at Boulder, Boulder, CO

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Abstract Body: Induced currents control the interaction between most unmagnetized solar system bodies and their plasma environment. This presentation reviews the properties of these induced currents, how they result in different types of interactions and "induced magnetospheres" and how induced currents are also produced within the bodies themselves. These later currents not only affect the magnetospheric interaction, but also allow soundings of the interior structure of solar system bodies, for example the properties of sub-surface oceans inside the Galilean satellites.

One type of current is induced by the convection –u x B electric field of the upstream plasma. This may drive currents through a planet’s (or moon’s) ionosphere, or currents due to pickup ionization in the body’s exosphere. In the case of bodies in a high β plasma, this leads to draping of the upstream magnetic field, diversion of the flow around the body and the formation of a “induced magnetosphere.” This is the case for Venus, Mars, comets and Saturn’s moon Titan. In a low β plasma, such that upstream of Jupiter’s Io and Europa and Saturn’s moon Enceladus, the induced currents produce Alfvén wings. A second type of induced entirely with currents flowing entirely within a body are due to a time-dependent upstream field. Although the curst of the body may be insulating, the changing magnetic field produces induced currents in any conductive layer within the body. The resulting induced magnetic fields affect the plasma interaction outside the body. In the case of Mercury, this is believed to limit compression of the upstream magnetosphere. In the case of all four of Jupiter’s Galilean moons, the time dependent field is due to the rotation of the planet and the tilt of its magnetic field. Induced signature have been reported for all of these moons, and interpreted as a metallic core, for Io, or a sub-surface ocean, in the case of Europa, Ganymede and Callisto. This allows magnetic field measurements to probe the internal structure of these moons, and is currently the best evidence for such sub-surface oceans. An active topic of current research is modeling these currents, both external and internal, to refine this magnetic sounding technique.

Abstract ID: 94539

Title: Explorations of Solar Activity and the Heliophysical Environment to Interplanetary Space Weather

Presenter/First Author: Madhulika Guhathakurta, NASA Headquarters/NASA Ames Research Center, Mountain View, CA

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Abstract Body: As human activity expands into the solar system, the need for accurate space weather and space climate forecasting is expanding, too. Space probes are now orbiting or en route for flybys of Mercury, Venus, Earth and the Moon, Mars, Vesta, Ceres, Saturn, and Pluto. Agencies around the world are preparing to send robotic spacecraft into interplanetary space. Each of these missions (plus others on the drawing board) has a unique need to know when a solar storm will pass through its corner of space or how the subsequent solar cycle will behave. Ultimately, astronauts will follow, traveling beyond Earth orbit, and their need for interplanetary space weather and climate forecasting will be even more compelling.

Until recently, forecasters could scarcely predict space weather in the limited vicinity of Earth. Interplanetary forecasting was even more challenging. This began to change in 2006 with the launch of the twin STEREO probes followed almost four years later by the Solar Dynamics Observatory. These three spacecraft along with SOHO now surround the sun, monitoring active regions, flares, and coronal mass ejections around the full circumference of the star. No matter which way a solar storm travels, the STEREO-SOHO-SDO fleet can track it. Observations from future missions like Solar Probe Plus, Solar Orbiter and Aditya-L1 will greatly enhance our understanding of the inner heliosphere from a solar system perspective. Missions like SDO and Kepler are giving us a better view of sun-like stars and their inner workings to understand their cyclic behavior, while missions like MAVEN and JUNO are investigating interaction of solar radiation and solar wind with Mars’s upper atmosphere and Jupiter’s intense auroras, a branch of heliophysics called “comparative heliophysics”.

Finally, scientific research could be the greatest beneficiary of comparative heliophysics/interplanetary space weather. What happens to asteroids, comets, planetary rings, and planets themselves when they are hit by solar storms? Finding out often requires looking at precisely the right moment. As the scope of space weather forecasting expands to other planets, it also interacts with climate research. Climate refers to changes in planetary atmospheres and surfaces that unfold much more slowly than individual storms. There is no question that solar activity is pertinent to climate time scales. The radiative output of the Sun, the size and polarity of the Sun’s magnetic field, the number of sunspots, and the shielding power of the Heliosphere against cosmic rays all change over decades, centuries, and millennia.
To capitalize on the science that will naturally emerge from the growth and modernization of the observational assets, researchers from many different fields will have to work together. Interplanetary space weather and climate forecasting is essentially interdisciplinary. Progress requires expertise in plasma physics, solar physics, weather forecasting, planetary atmospheres, and more. In the past, NASA has assembled such teams under the umbrella of virtual institutes, where widely dispersed researchers confer from a distance using the Internet and other forms of tele-collaboration. Interplanetary space weather might call for a similar approach. One thing is sure: The Sun is not waiting and the stakes are as big as the solar system itself.

Abstract ID: 94551

Title: Electric Currents in the Solar Atmosphere: Diagnostics, Properties, and Possible Role in Pre-Eruption Dynamics

Presenter/First Author: Manolis K Georgoulis, Academy of Athens, Athens, Greece

Presenter/First Author Email: manolis.georgoulis@academyofathens.gr

Abstract Body: The advent of solar vector magnetography, albeit only at photospheric level, typically, has enabled intriguing new capabilities toward the study of solar atmospheric magnetism. A prominent such capability is the evaluation of Ampere’s law in its differential and integral formats. This allows both the calculation of the vertical component of the photospheric electric current density and, notably, the calculation of the total electric current that enters the solar atmosphere via emerging magnetic flux crossing the photospheric interface. We review these diagnostics and the properties of both current density and total current of solar magnetic structures, comparing the results with classical theoretical predictions. The [non]-neutralization of electric currents along magnetic polarity inversion lines is another key issue viewed here under a new perspective, namely the way in which it may be contributing to the triggering of solar eruptions. The results of this analysis have been tailored for solar physics research but apply also to Sun-like, magnetically active stars with a dynamo and a convection zone and, apparently, to every magnetized system in nature that involves a low-beta plasma parameter.

Abstract ID: 94857

Title: Influence of auroral streamers on rapid evolution of SAPS flows

Presenter/First Author: Bea Gallardo-Lacourt, University of California Los Angeles, Los Angeles, CA

Presenter/First Author Email: bgallardo@atmos.ucla.edu

Abstract Body: An important manifestation of plasma transport in the ionosphere is Subauroral Polarization Streams or SAPS, which are strong westward flows lying just equatorward of the electron auroral oval and thus of enhanced ionospheric conductivities of the auroral oval. Previous studies suggested that the strongest SAPS occur when field-aligned currents (FAC) are more intense. While SAPS are known to intensify due to substorm injections, recent studies showed that large variability of SAPS flow can occur well after substorm onset and even during non-substorm times. These SAPS enhancements have been suggested to occur in association with auroral streamers that propagate equatorward, a suggestion that would indicate that plasma sheet fast flows propagate into the inner magnetosphere and increase subauroral flows. We present auroral images from the THEMIS ground-based all-sky-imager array, 2-d line-of-sight flow observations from the SuperDARN radars, and FAC observations from AMPERE to investigate systematically the association between SAPS and auroral streamers. We surveyed events from December 2007 to May 2013 for which high or mid-latitude SuperDARN radars were available to measure the SAPS flows, and identified 104 events. For streamers observed near the equatorward boundary of the auroral oval, we find westward flow enhancements of ~700 m/s slightly equatorward of the streamers. Our statistical study shows that 60% of the westward flow enhancements are associated with streamers that reach close to the auroral equatorward boundary. In addition, we have found that the majority of the remaining events are flow increases associated with IMF changes. We have also characterized the SAPS flow channel width and timing relative to streamers reaching radar echo meridians. Using AMPERE, we also determine evolution of R2 FACs during SAPS flow enhancements associated with auroral streamers. The strong influence of auroral streamers on rapid evolution of SAPS flows suggests that transient fast earthward plasma sheet flows can lead to westward SAPS flow enhancements in the subauroral region, and that such enhancements are far more common than only during substorms because of the frequent occurrences of streamers under various geomagnetic conditions.

Abstract ID: 94858

Title: Mapping Bursty Bulk Flows Current to the Ionosphere using OpenGGCM-CTIM Model

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Abstract Body: Mapping Bursty Bulk Flows Current to the Ionosphere using OpenGGCM-CTIM Model
Bursty bulk flows (BBFs) are important part of magnetotail dynamics as they transfer 60 – 100% of energy, mass and magnetic flux in the magnetosphere. BBFs are interpreted as plasma bubbles, magnetic flux tubes with low entropy content in comparison to the surrounding field, observed during both disturbed and quiet time in the plasma sheet boundary layer (PSBL) as well as center plasma sheet. Another important aspect of BBFs is that they are associated with field-aligned current (FAC) similar to substorm current wedge (SCW). Such currents are along the outer edge of the bubble which can be mapped to the ionosphere. In this study, we use global numerical MHD model of the Earth, OpenGGCM-CTIM model, to map BBF’s FAC to the ionosphere.

Abstract ID: 94876

Title: Electric Currents in the Solar Atmosphere

Presenter/First Author: Gregory D Fleishman, New Jersey Institute of Technology, Edison, NJ

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Abstract Body: In this talk I discuss probing and the role of electric currents in solar atmosphere, primarily—in chromosphere and corona, in supporting the force-free magnetic configurations, the plasma dynamics, energy release, and acceleration and transport of nonthermal particles. In particular, I discuss electron and ion components forming electric current in a multi-component plasma, effect of the electric current on the Alfvén wave properties, and current neutralization due to return currents.

Abstract ID: 94880

Title: Currents and associated electron scattering and bouncing near the diffusion region at Earth’s magnetopause

Presenter/First Author: Benoit Lavraud, IRAP/CNRS, Toulouse,

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Abstract Body: Based on high-resolution measurements from NASA’s Magnetospheric Multiscale Mission, we present the dynamics of electrons associated with current systems observed near the diffusion region of magnetic reconnection at Earth’s magnetopause. Using pitch angle distributions (PAD) and magnetic curvature analysis, we demonstrate the occurrence of electron scattering in the curved magnetic field of the diffusion region down to energies of 20 eV. We show that scattering occurs closer to the current sheet as the electron energy decreases. The scattering of inflowing electrons, associated with field-aligned electrostatic potentials and Hall currents, produces a new population of scattered electrons with broader PAD which bounce back and forth in the exhaust. Except at the center of the diffusion region the two populations are collocated and appear to behave adiabatically: the inflowing electron PAD focuses inward (toward lower magnetic field), while the bouncing population PAD gradually peaks at 90° away from the center (where it mirrors owing to higher magnetic field and probable field-aligned potentials).

Abstract ID: 94883

Title: Jupiter’s Magnetospheric Current System: Implications for Juno and JUICE

Presenter/First Author: Pontus C. Brandt, Johns Hopkins Univ/APL, Laurel, MD

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Abstract Body: Based on high-resolution measurements from NASA’s Magnetospheric Multiscale Mission, we present the dynamics of electrons associated with current systems observed near the diffusion region of magnetic reconnection at Earth’s magnetopause. Using pitch angle distributions (PAD) and magnetic curvature analysis, we demonstrate the occurrence of electron scattering in the curved magnetic field of the diffusion region down to energies of 20 eV. We show that scattering occurs closer to the current sheet as the electron energy decreases. The scattering of inflowing electrons, associated with field-aligned electrostatic potentials and Hall currents, produces a new population of scattered electrons with broader PAD which bounce back and forth in the exhaust. Except at the center of the diffusion region the two populations are collocated and appear to behave adiabatically: the inflowing electron PAD focuses inward (toward lower magnetic field), while the bouncing population PAD gradually peaks at 90° away from the center (where it mirrors owing to higher magnetic field and probable field-aligned potentials).
Abstract Body: In this presentation we will review our current understanding of Jupiter’s large-scale current system, its relation to the Jovian aurora, and Jupiter’s giant magnetodisc, and the dependence on external solar wind drivers versus internal mass loading. Given this context we will contrast specific features of the Jovian magnetosphere to those of Saturn and Earth. The major latter part of the presentation will give an overview of how the Juno and JUICE missions to Jupiter will provide unprecedented insight into these two fundamental space physics problems. The NASA Juno spacecraft will be inserted into its orbit around Jupiter in July 2016 where it will conduct low-altitude traversals of Jupiter’s poles and probe the magnetodisc at several radial distances. Equipped with UV and visible cameras, a magnetometer, wave, plasma and energetic particle measurements, Juno will detail the location, distribution and variability of the FACs, as well as the physical mechanisms of energy transfer. The ESA JUICE mission is planned to launch in June 2022 and arrive at the Jovian system in 2030. JUICE is a large spacecraft carrying ten investigations. During its extensive campaign in the Jovian equatorial magnetosphere it will map the three-dimensional structure of the magnetodisc, plasma flow velocities and densities, and the anisotropies of energetic particles to better understand the formation and force-balance of a magnetodisc.