Oral Abstracts

Presenting Author: Alken P.

Abstract Title: Swarm Equatorial Electric Field Inversion Chain

Abstract Topic: First science results

The day-time eastward equatorial electric field (EEF) in the ionospheric E-region plays a crucial role in equatorial ionospheric dynamics. It is responsible for driving the equatorial electrojet (EEJ) current system, equatorial vertical ion drifts, and the equatorial ionization anomaly (EIA).

Due to its importance, there is much interest in accurately measuring and modelling the EEF for both climatological and near real-time studies. The Swarm satellite mission offers a unique opportunity to estimate the equatorial electric field from measurements of the geomagnetic field. Due to the near-polar orbits of each satellite, the on-board magnetometers record a full profile in latitude of the ionospheric current signatures at satellite altitude. These latitudinal magnetic profiles are then modelled using a first principles approach with empirical climatological inputs specifying the state of the ionosphere, in order to recover the EEF. We will present some first results of Swarm-derived EEF estimates, and compare them with independent ground measurements.

Presenting Author: Amm O.

Abstract Title: Maps of Ionospheric Conductances, Currents, and Convection from the Swarm Multi-Satellite Mission

Abstract Topic: Presentation of user projects and their initial results

a) The recently launched ESA Swarm spacecraft mission is the first dedicated multi-satellite ionospheric mission with two low orbiting spacecraft that are flying in parallel in a distance of ~ 100 km, thus allowing deriving spatial gradients of ionospheric parameters not only along the orbits, but also in the direction perpendicular to them. In addition, a third satellite with a slightly higher orbit regularly crosses the paths of the lower spacecraft pair.

b) Using the Swarm magnetic and electric field instruments, we present a novel technique that allows deriving 2-dimensional (2D) maps of ionospheric conductances, currents, and convection in the area between the trajectories of the two parallel flying spacecraft, and even to some extent outside of it. This technique is based on Spherical Elementary Current Systems (SECS).

c) We present several test cases of modelled ionospheric situations from which we calculate virtual Swarm data, and show that the technique is able to reconstruct the model electric field (or convection), horizontal currents, and conductances with very good to excellent accuracy. Larger errors arise for the reconstruction of the 2D field-aligned currents (FAC) map, especially in the area outside of the spacecraft orbits. However, even in this case the general pattern of the model FAC is recovered, and the magnitudes are valid in an integrated sense. Finally, using an MHD model run, we show how our technique allows to estimate the ionosphere-magnetosphere coupling parameter K, if conjugate multi-point observations of the magnetospheric magnetic and electric field are available, as they can be obtained, e.g., from the ESA Cluster mission.

d) Our maps have the potential to be standard products from Swarm to be produced whenever the satellites pass over the auroral zone.

Presenting Author: Balasis G.

Abstract Title: Magnetospheric ULF Wave Observations with Swarm Mission

Abstract Topic: First science results, Plans for exploitation projects

Recently developed automated methods for deriving the characteristics of ultra-low frequency (ULF) waves (Balasis et al., 2012, 2013) can be effectively applied to the Swarm datasets in order to retrieve, on an operational basis, new information about the near-Earth electromagnetic environment.

Processing Swarm measurements with these methods will help to elucidate the processes influencing the generation and propagation of ULF waves, which in turn play a crucial role in magnetospheric dynamics. Moreover, a useful platform based on a combination of wavelet transforms and artificial neural networks has been developed to monitor the wave evolution from the Earth's magnetosphere (using Cluster observations) through the topside ionosphere (with Swarm measurements) down to the surface (using ground-based magnetometer arrays recordings). Here we present the first ULF wave

observations by Swarm, obtained by applying our analysis tools to the first six months of the mission's Absolute Scalar Magnetometer (ASM) and Vector Field Magnetometer (VFM) data.

Presenting Author: Buchert S.

Abstract Title: Electron density variation in the South Atlantic anomaly

Abstract Topic: First science results

During the commissioning phase the Swarm satellites scanned the region of the South Atlantic anomaly. The variation of the electron density Ne from the LPs is calculated as the standard deviation of detrended pieces of time series over 31 2 Hz samples. In addition to expected strong variation of Ne at high latitudes, it is also enhanced near the South Atlantic anomaly. According to commissioning reports also the L1 carrier phase of the Swarm GPS receivers was most disturbed in roughly the same regions. An increase of the electron density itself was seen only at high latitudes, not over the South Atlantic.

Presenting Author: Burchill J.

Abstract Title: Swarm Observations of Low-Altitude Cusp Ion Upflow

Abstract Topic: First science results, Presentation of user projects and their initial results

The nearly vertically-aligned magnetic fields of Earth's magnetic cusp regions facilitate vertical transport of energy and plasma between the solar wind and the topside ionosphere. One consequence of this coupling is the transport of cold, heavy ions front he ionosphere to the magnetosphere, where changes in the local mass density affect processes such as Alfven wave propagation and magnetic reconnection. Swarm measurements of ion up flow can enable investigations of the low-altitude (500 km) part of this coupling. We present new Swarm observations of the statistical nature of ion up flow in the magnetic cusps, including morphology and variability. Initial analysis indicates a clear and significant enhancement of ion up flow velocities of a least several hundred m/s in the polar cusps. We will discuss implications of the Swarm up flow observations for making advances on understanding the low-altitude heavy-ion transport problem.

Presenting Author: Chulliat A.

Abstract Title: Rapid core field variations just before Swarm

Abstract Topic: Presentation of user projects and their initial results

Geomagnetic field models from CHAMP and Oersted data recently revealed the existence of rapid core field variations over the last decade, having time scales of only a few years. These variations are superimposed on more slowly varying field fluctuations and can be detected by directly modelling the secular acceleration (SA), i.e., the second-order time derivative of the field. At the Earth's surface, rapid core field variations lead to the occurrence of sudden polarity changes of the SA, also known as geomagnetic jerks. Three recent jerks, in 2003, 2007 and 2011, mark the beginning or end of intense SA pulses at the core surface, in 2006 and 2009. We will report on the use of geomagnetic models based upon magnetometer data from the Defence Meteorological Satellite Program (DMSP) to investigate rapid core field variations between the end of the CHAMP mission (September 2010) and the beginning of the Swarm mission (November 2013). Such an analysis is made possible by an improved calibration scheme for DMSP magnetometer data. DMSP data reveal that there is yet another SA pulse at the core surface in 2012, following the 2011 jerk. The 2006, 2009 and 2012 pulses have the space-time structure of a stationary wave of period 6 years over the Atlantic region. We will discuss how Swarm data, once available over a long enough time interval for direct SA calculation, could shed some new light on the space-time characteristics and origin of this wave and other rapid core field variations.

Presenting Author: Doornbos E.

Abstract Title: First look at thermosphere density results from the Swarm Level

Abstract Topic: First science results, Presentation of the outcome of the Cal/Val activities

The three satellites of ESA's Swarm mission each carry an accelerometer, a GPS receiver and a set of star cameras. Together, these instruments allow for the retrieval of information on thermospheric density, and possibly also thermospheric wind components. In combination with the magnetic and electric field measurements on the same satellite, these data can provide insights on the coupling processes in the thermosphere-ionosphere-magnetosphere system.

The algorithm for producing density and wind data, which was previously developed and tested using data from the CHAMP, GRACE and GOCE satellites, is now for the first time applied to Swarm data. The Swarm mission offers the possibility to extend the thermosphere data sets of these previous missions into the next solar cycle. In addition, the availability of data from three identical satellites, which during the commissioning have already been commanded to perform several interesting attitude manoeuvres, offers the possibility for extensive cross-validation and calibration of the data and models used in this data processing chain. This presentation offers a first look at the performance of the density data processing, which is part of the activities of the Swarm Satellite Constellation Application and Research Facility (SCARF). Special attention will be given to the assessment of the performance of the new instruments, and the challenges and opportunities that are associated with the relatively high initial orbital altitude.

Presenting Author: Du A.

Abstract Title: Chinese Geomagnetic Small Multi-satellite Mission

Abstract Topic: Plans for exploitation projects

Executive Summary

Accurate measurements of the geomagnetic field are one of the very few ways by which we can probe the properties of the Earth's interior, especially concerning dynamic processes in the core and mantle. The magnetic field is a witness of the past history of the Earth. It is also an agent of the Earth's evolution. In addition, the geomagnetic field and its interaction with the solar wind play an important role in forming the external environment of the Earth in a way that also affects atmospheric processes related to climate and weather.

The magnetic field measured at or near the surface of the Earth is the superposition of the contributions from a wealth of sources: the fluid core, the magnetisation of rocks in the Earth's crust, electric currents flowing in the ionosphere and magnetosphere, and currents induced in the Earth by the time-variations of the field. The magnetic field is maintained against ohmic decay by a dynamo mechanism. The latter takes place, within the Earth's core, on longer timescales and, in all likelihood, shorter length-scales than the variations of the field that have been recorded from satellites for the past 10 years. The goal is to partly bridge this gap. The benefit and the challenge of the CGS mission are related to the sophisticated separation of the various sources of magnetic field, and the accurate determination of the spatial and temporal structure of them all. ESA's currently planned Swarm geomagnetic satellite mission will aim to accomplish this separation, but the descoping of the mission will create challenges. Multi-point measurements, as envisaged in the CGS mission, are required for proper separation.

The CGS concept consists of a constellation of five satellites in orbits that evolve relative to one another. Each satellite will provide high-precision and high-resolution measurements of the vector magnetic field. In combination, they provide the necessary observations for the global high-precision survey of the geomagnetic field that is needed to model all sources of the geomagnetic field. An optimal launch strategy requires 2 launches. One satellite is in an orbit close to the equatorial plane. Four satellites are in polar orbits separated by 45° after 6 months. This leads to excellent global sampling and especially good local time sampling.

The mission will provide a new model of the near-Earth magnetic field every 2-4 months. It also will provide details of the induced currents that will give new insight into the electrical conductivity structure of the mantle. This has the potential for exciting synergies between results from geomagnetism and determinations of the state of the mantle from seismic tomography. Combined with results from ESA's Swarm mission, which will undoubtedly supply the highest fidelity determination of the lithospheric magnetic field to date, one can envisage a correction of the results of colony for the effects of the lithosphere, thus adding value to the measurements.

Scientific objectives

- Earth's core

The morphology of the field at the core surface is the primary target. Whilst the static field and its rate of change can be well determined, a proper description of the secular acceleration is at the very frontier of current research. Recent secular acceleration models calculated from satellite data differ for spherical harmonic (SH) degrees above 7 but also for the longest wave-lengths. This is an indication of the difficulty in separating the core field from the external fields. That time resolution can be improved by having a number of satellites monitoring the field at different local times. The CGS satellites flying in 4 polar orbital planes will yield models with twice the resolution of models based on Swarm data. It is anticipated that the CGS mission will allow better determination of the secular acceleration.

- Electromagnetic tomography of the Earth's mantle

One of the major research aims of the mission is to perform electromagnetic tomography of the mantle from satellite datasets. The deliverable from such studies would be 3-D maps of electrical conductivity of the upper- and mid-mantle, most likely down to roughly 1500km, though this figure is difficult to give firmly as resolution, namely the ability to accurately retrieve structure, gradually fades away with depth. The methodology for performing this task is to use magnetic fields that are external to the satellite, originating in the magnetospheric ring current, as sources, and record the response of the Earth to such excitation. Since the internal and external parts can be determined from a spherical harmonic analysis of satellite data, it is thus possible to infer electrical conductivity of the mantle from such a response. Note that the electrical conductivity is related to the response in a very non-linear manner, and the entire inverse problem is highly nonlinear and can only be solved in an iterative manner.

We believe that the CGS mission can perform this task exceptionally well as a result of the innovative constellation design. It is essential that the satellite constellation evolve into a formation with satellites in 4 planes, each separated by 45 degrees of longitude. This results in coverage of local times every three hours. In addition the satellite flying in the low-inclination orbit will fly very rapidly through all local times, and we believe this will be beneficial for enhanced recovery.

- Lithospheric field

It is not the aim of the CGS mission to refine the lithospheric field beyond that achieved by the last days of the CHAMP mission, or what will be achieved by ESA's upcoming Swarm mission. The relative high altitude (550 km) of the CGS satellites is a limiting factor for a direct determination of the small-scale features of the lithospheric field. Instead, the CGS mission can make direct use of the best determined lithospheric field model to remove crustal effects from the data.

General Mission Characteristics

In general terms, the requirement to the mission set by the scientific objectives is for the vector components of the geomagnetic field to be measured globally, continually and very accurately.

The absolute accuracy of the magnetic field measurements should be better than 0.3 nT. The major limitation for the accuracy of the vector measurements is the accuracy of the attitude determination. The tri-directional star tracker and the optical bench construction, which secures a common frame of reference for the magnetometer sensor and the attitude determination, provide the solution for this. The high accuracy requirement furthermore sets tight limits on the magnetic disturbance level, from the satellite system that can be tolerated at the sensor. Finally, an accuracy of 0.3 nT for the magnetic field measurements translates into an additional requirement for the position determination to be better than 15 m. The latter is easily obtained with current GPS receivers.

The requirement of global coverage concerns both geographic and local time coverage. This is met by launching the four of the five satellites into two near-polar circular orbits, as illustrated in the figure, with very similar inclinations. The two orbital planes are chosen to be 90 degrees apart. The fifth satellite should be placed in an orbit close to the equatorial plane; in this low inclination (approximately 50 degree) orbit it moves rapidly through all local times within one orbit (taking ~90 minutes of satellite time). This is expected to bring great benefits in the recovery of the space-time structure of large-scale magnetospheric field contributions, which is favourable situation for mantle electrical conductivity determination.

Payload Description

The scientific payload of CGS mission consists of three instruments supported by timing and orbital position from the Global Positioning System receiver (GPS). Fluxgate magnetometer provides high quality magnetic field vector measurement; Absolute Scalar Magnetometer calibrate the vector field magnetometer to maintain the absolute accuracy; Advanced Stellar Compass system gives accurate reference coordinates according stellar images. The Weight of Payload is less than 25kg.

Presenting Author: Dunlop M.

Abstract Title: Swarm-Cluster Coordination: the Ring Current, Cusp and Adjacent FACs

Abstract Topic: First science results

One of the four primary science objectives of Swarm is to investigate the external electric currents flowing in the magnetosphere and ionosphere. The ring current and connecting R2 field aligned currents (FAC) are a dominant influence on the geomagnetic field at low Earth orbit (LEO) and these are sampled in situ by the four Cluster spacecraft every perigee pass. Coordination of the configuration of the three Swarm spacecraft with the constellation of the four Cluster spacecraft has been planned through joint operations; providing a set of distributed, multi-point measurements covering this region. A particularly close coordination of all spacecraft is expected during the beginning of the Swarm operations. In anticipation of such direct comparison of Swarm and Cluster, preliminary study of the morphology and influence of the ring current using Cluster has produced a full-circle determination of the in-situ RC and associated FACs directly from the 4-spacecraft perigee observations. Such coordinated measurements of the current systems from ground to the (inner) magnetosphere are highly desirable and may also be used to validate the Swarm constellation data. We report here preliminary results of joint science targets, including coordinated cusp encounters; the comparative significance of the connecting R2 FACs, and the use and application of new analysis techniques derived from the calculation of curl B and magnetic gradients to compare estimates of the current distributions.

Presenting Author: Erwan T.

Abstract Title: Inverse Geodynamo Modelling and Errors in Magnetic Field Observations

Abstract Topic: Plans for exploitation projects

The Earth's magnetic field is generated by a large variety of physical processes taking place in the core, the crust, the ionosphere, and the magnetosphere. The magnetic field is mainly produced in the outer core by a dynamo process whose mechanisms are formally well known but whose parameter values are uncertain and out of reach of numerical simulations. Inverse geodynamo modelling (see Fournier et al., this meeting) consists in estimating the vector of parameters that govern the physics of the Earth's dynamo from a set of magnetic field observations. This requires isolating in the total measured signal the magnetic field contributions emanating from the Earth's core, to estimate the contributions of the unresolved scales, and to define realistic bounds for the large-scale uncertainties.

In this presentation, we first attempt to characterize different sources of errors that noise or mask the core magnetic field structures. We more specifically focus on the crustal and external magnetic fields and discuss how the Swarm data will mitigate some of the long-standing ambiguities. We then use these results in order to build a priori an error covariance matrix that will be subsequently used in the inverse geodynamo modelling framework that will be subsequently used in the inverse geodynamo modelling framework.

Presenting Author: Finlay C.

Abstract Title: Use of Swarm data in an Update of the CHAOS-4 Field Model

Abstract Topic: First science results

The CHAOS series of geomagnetic field models describe the internal geomagnetic field and its time variations to high resolution in both space and time. These models have previously been derived using satellite magnetic data collected by the CHAMP, Oersted and SAC-C missions, along with monthly mean ground observatory data. Here we present a new model update, called CHAOS-4plus_V3, which in addition includes more than 6 months of Swarm Level 1B VFM data. As for CHAOS-4, a time-dependent internal field is solved for up to degree 20, and regularization of the third time derivative of the field is applied at the core-mantle boundary. We present the evolution of the Swarm constellation up until June 2014 and discuss our selection of quiet-time, night side, and data. We find our updated CHAOS field model simultaneously fits well the data from all six of the satellites. Furthermore, residuals for the three Swarm satellites display similar, and expected, trends as a function of geomagnetic dipole latitude. We further find that the new model provides a good description of observatory secular variation, capturing rapid field evolution events during the past decade. Maps of the core surface field, its secular variation, the time changes in the model secular variation for specific coefficients, and the evolution of the model secular acceleration are presented. From our initial investigations, we conclude that Swarm data seems suitable for building high resolution models of the time-dependent core field. Further work, and a longer time span of data, is still required to fully document this point. Like previous models, CHAOS-4plus_V3 will be made available from the CHAOS-4 webpage: http://www.spacecenter.dk/files/magnetic-models/CHAOS-4/.

Presenting Author: Forbes J.

Abstract Title: Atmosphere-Ionosphere Wave Coupling as Revealed in Plasma Densities and Drifts

Abstract Topic: First science results, Presentation of user projects and their initial results

(a) Introduction. The ionosphere is coupled to the lower atmosphere through the vertical propagation of solar thermal tides with 24-, 12-, and 8-hour periods and planetary waves with periods between about 2 and 20 days. These waves generate electric fields in the dynamo region (100-150 km) which then map along magnetic field lines and redistribute plasma through ExB drifts in the 200-1000 km height regime. Some also penetrate directly to higher altitudes and exert their influence on the ionosphere directly through wind transport along field lines. These processes impose local-time-dependent latitude vs. longitude structures on the ionosphere that vary with time according to the planetary wave periods and in response to time-dependent sources. In addition, these processes undergo modulation by the time-varying solar flux through its effects on dynamo-region conductivity and F-region plasma-neutral coupling, as well as by the longitude-dependent magnetic field.

(b) Method. Through visualization including animation, we illustrate the day-to-day evolution of latitude vs. longitude structures of plasma densities and drifts from Swarm EFI and LP measurements. Space-time spectral decomposition of this variability is performed and interpreted in the context of prior analyses of CHAMP and TIMED/SABER neutral density and temperature measurements.

(c) Results. The spectra reveal longitude components and wave periods that are identifiable with solar non-migrating tides and planetary waves known to influence the generation of dynamo electric fields in the ionospheric E-region.

(d) Discussion & Conclusion. We conclude that a significant degree of quiet-time ionospheric "complexity" is attributable to tidal and planetary wave influences originating in the lower atmosphere. These effects are further modulated by solar flux variability and the magnetic field geometry. The combined neutral and plasma measurements offered by Swarm will enable a self-consistent formulation of atmosphere-ionosphere coupling to emerge.

Presenting Author: Fournier A.

Abstract Title: A Secular Variation Model for IGRF-12 Based on Swarm Data and Inverse Geodynamo Modelling: Methodological Backbone

Abstract Topic: Plans for exploitation projects

We are planning to propose a secular variation candidate model for the 12th generation of the international geomagnetic reference field, spanning the years 2015-2020.

The novelty of our approach stands in the initialization of a 5-yr long integration of a numerical model of Earth's dynamo by means of inverse geodynamo modelling, as introduced by Aubert (GJI, 2014). This inverse technique combines the information coming from the observations (in the form of an instantaneous estimate of the Gauss coefficients for the magnetic field and its secular variation) with that coming from the multivariate statistics of a free run of a numerical model of the geodynamo. The Gauss coefficients and their error covariance properties will be determined from Swarm data along the lines detailed by Thébault et al. (EPS, 2010). The numerical model of the geodynamo will be the so-called Coupled Earth Dynamo model (Aubert et al., Nature, 2013), whose variability possesses a strong level of similarity with that of the geomagnetic field.

The goal of this presentation is to illustrate and assess the potential of this methodology by applying it to the recent 2009-2014 time interval, with an initialization based on CHAMP data.

This work is partially supported by the French “Agence Nationale de la Recherche” under the grant ANR-11-BS56-011 (http://avsgeomag.ipgp.fr) and by the CNES.

Presenting Author: Gjerloev J.

Abstract Title: Characteristics of the Field-Aligned Current System

Abstract Topic: First science results, Presentation of user projects and their initial results

We present a discussion of the Swarm derived field-aligned current (FAC) densities and the assumptions this data product is based on. First glimpse of the spatiotemporal behaviour of the FAC system as provided by Swarm will be shown. We complement these observations by a comprehensive statistical study of the temporal behaviour of the field-aligned currents. In that study we use data obtained by the Science and Technology 5 (ST5) mission which consisted of three identical spacecraft making simultaneous measurements of the magnetic field perturbations at three points along the same orbit. The separation of the spacecraft’s varied throughout the mission from seconds to about 12 minutes. We have performed a comprehensive analysis of the entire dataset. We identified more than 4000 satellite pairs of auroral oval crossings and determined the coherence between the two sets of satellite observations. By taking advantage of the variable inter-satellite separation we have determined the coherence as a function of field-aligned scale size and satellite separation. This 2D coherence distribution provides information of the spatiotemporal characteristics of the field-aligned current system.

Presenting Author: Hulot G.

Abstract Title: On the possibility of using Swarm's Absolute Scalar Magnetometer experimental vector field measurements to produce alternative geomagnetic field models and North East Centre vector data

Abstract Topic: Presentation of the outcome of the Cal/Val activities, Presentation of user projects and their initial results, Plans for exploitation projects

In addition to providing the reference absolute scalar measurements on the three satellites of the Swarm mission, each Absolute Scalar Magnetometer (ASM) can also, and simultaneously, provide independent vector field measurements. These appear to be of very stable quality, with no apparent biases. In addition, comparisons of such measurements with readings from the Vector Field Magnetometer (VFM, located some distance away along the boom and used to produce the nominal Swarm Level1b vector data) show that the mechanical link between both instruments is very stable on all three satellites. Since the VFM itself is rigidly linked to the Star Tracker (STR) system used for its attitude restitution, this then suggests that the STR system could also be used for ASM attitude restitution. This finally opens the possibility of estimating, as part of the geomagnetic field modelling procedure, the Euler angles describing the rotation between the ASM and STR instrument frames, and producing magnetic field data in the North East Centre (NEC) reference frame, directly from ASM vector measurements, in much the same way NEC frame magnetic field data are nominally derived from Level1b VFM vector data. Although the mechanical rigidity of the STR system with respect to the ASM may be expected to be less stable than that (optimized) with respect to the VFM, such independent data could provide opportunities to validate nominal Leve1b NEC frame vector data and propose alternative geomagnetic field models. In this presentation, we will report on our on-going efforts to produce such data and models, and discuss possible early conclusions.

Presenting Author: Iyemori T.

Abstract Title: 3D Structure and Global Distribution of Small-scale Currents in the Ionosphere Generated by the Acoustic-Gravity Waves from Lower Atmosphere - (1) Confirmation of the Field-aligned Currents in Middle and Low Latitudes by the SWARM Satellites

Abstract Topic: First science results

It is known that the lower atmospheric disturbances propagate to the ionosphere as the acoustic-gravity waves. Since a magnetic pulsation caused by the 2004 Great Sumatra Earthquake was found (Iyemori et al., 2005), we have been investigating the coupling process between the lower atmosphere and ionosphere/magnetosphere through the acoustic gravity waves (Matsumura et al., 2011; Iyemori et al., 2013). From the analysis of the data obtained by the Oersted and CHAMP satellites, we found that the small-scale magnetic fluctuations with amplitude about 1 nT or less having apparent period along satellite orbit about 10-30 seconds exist almost always on the dayside, and a CHAMP data analysis (Nakanishi et al., 2014) strongly supported the idea that they are the spatial structure of small-scale field-aligned currents and their origin is in the lower atmosphere. In this paper, we present initial results of the SWARM dual-spacecraft FAC analysis by using traditional methods but also making use of the curl-B approach to confirm that the small fluctuations are caused by spatial structures of field-aligned currents. From the comparison of single/dual satellite FAC results we can estimate the spatial scales of FACs both in latitudinal and longitudinal directions.

Presenting Author: Jackel B.

Abstract Title: Optical Aurora during Swarm Over-flights of Western Canada

Abstract Topic: Plans for exploitation projects

Visible aurora with extensive spatial and temporal structure has been observed in conjunction with several Swarm passes over Western Canada.

We will present a brief overview of ground-based instrument capabilities in this region, illustrated with recent observations from April 30 2014.

Similarities and differences between spacecraft and ground-based data will be explored, followed by a discussion of some opportunities for the upcoming winter observing season.

Presenting Author: Jackson A.

Abstract Title: Swarm Science: the Physical Background and Open Questions

Abstract Topic: An international media event focusing on the role of Swarm within the Earth sciences

Despite four hundred years of geomagnetic enquiry, much remains to be learned. We review several of the open questions that motivate a mission such as Swarm.

Presenting Author: Knudsen D.

Abstract Title: Swarm EFI Overview and Science Highlights

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems), First science results

The Swarm Electric Field Instruments have been operating nominally on orbit since a few weeks after launch, producing data products that include ion drift velocity, ion and electron temperature, plasma density, and of course electric field at a rate of 2 per second.

Swarm represents the pioneer orbital flight of the Thermal Ion imagers from which ion velocity and temperature are derived; first results indicate that electric fields are resolved to a level of 0.3 mV/m (2-sigma) in regions of sufficient plasma density. Velocity measurement accuracy depends strongly on key calibration parameters derived from statistical properties of taken on orbit; refinements of these parameters are continuing. Spacecraft potential and electron density and temperature are derived from Langmuir probe data also derived through use of a pioneering technique of focused sweeps of bias voltage; these data are also promising and depend on calibration parameters that are being refined over time.

This talk provides an overview of initial scientific studies described in detail in other presentations. These include observation of ionospheric energy dissipation calculated with the aid of the electromagnetic Poynting vector; anisotropic heating of ionospheric plasma and its evolution with time; sensitive measurement of plasma up flow; and response of plasma convection to different auroral forms including diffuse aurora, pulsating aurora, and discrete auroral arcs. Swarm brings new measurement capability to bear on each of these topics by virtue of the precise, multi-point nature of its observations, and its unique ability to measure directional temperature and flow of low-energy ions.

Presenting Author: Kuvshinov A.

Abstract Title: Satellite Magnetic Signal due to Ocean Tidal Flow. Sensitivity Analysis based on Global 3D EM Simulations

Abstract Topic: Presentation of user projects and their initial results

A few scientific groups convincingly demonstrate that the magnetic fields induced by the lunar semidiurnal (M2) ocean flow can be identified in magnetic satellite observations. These results support the idea to use Swarm M2 magnetic signals to constrain upper mantle electrical conductivity in oceanic regions. In this study we perform global 3-D EM numerical simulations in order to investigate the sensitivity of M2 signals to conductivity distributions at different depths. The results of sensitivity analysis are discussed.

Presenting Author: Leger J.-M.

Abstract Title: On the in-flight calibration of the experimental absolute scalar magnetometer vector mode on board the swarm satellites

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems), Presentation of the outcome of the Cal/Val activities

While the role of the ASM is to provide absolute measurements of the magnetic field's strength for the in-flight calibration of the Vector Fluxgate Magnetometer, it can also deliver simultaneously vector measurements with no impact on its scalar performance. Since these scalar and vector measurements are both perfectly synchronous and spatially coherent, their comparison can be directly used to assess the ASM performances at instrument level with no need to correct for the various magnetic perturbations generated by the satellites. This presentation will detail the ASM vector calibration process, with an emphasis on the effects of the ASM operational conditions (mainly the sensor's temperature and attitude with respect to the ambient magnetic field, which determines the rotor angular position). The evolution of the instrument's parameters during the first six months of the Swarm mission will then be discussed. In particular the scalar residuals will be analysed to demonstrate both the noise performances of the ASM vector measurements and their excellent long term stability.

Presenting Author: Marghitu O.

Abstract Title: Auroral Electrodynamics with Swarm

Abstract Topic: Presentation of user projects and their initial results

The multi-point measurements of Swarm, conjugate at times with ground data, make possible for the first time a systematic examination of auroral electrodynamics questions difficult to address by single spacecraft data, in particular the ionospheric current closure and its effects on the magnetosphere–ionosphere–thermosphere coupling. The magnetic and electric field data from the two side-by-side Swarm spacecraft enable the investigation of the gradients along auroral arcs, typically disregarded by the 1D, infinite arc models, while the examination of more complicated, 2D auroral forms, may take advantage from all three satellites when in close formation. The gradients along the arc (and also, on a different scale, along the auroral oval) are potentially important at certain locations and times, for example in relation to the sub storm onset, and Swarm may help understanding the transition from the 1D arc to the 2D aurora. Swarm enables also a proper consideration of the neutral wind influence on auroral electrodynamics, in general disregarded as well. While in many cases the equivalent electric field associated with neutral winds is indeed rather small, its value can become significant when the background electric field is small too, as expected for example near the plasma convection reversal boundary. Last but not least, the low-altitude Swarm observations contribute to the comprehensive, multi-point exploration of the auroral current circuit, complementing the mid-altitude observations by the Cluster satellites, at the topside of the auroral acceleration region, and the high-altitude sampling of the inner plasma sheet by the THEMIS spacecraft.

Presenting Author: Masson A.

Abstract Title: Cluster Special Operations in Support of SWARM

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems)

The measure of the Earth's magnetic field is perturbed by the external electric currents flowing in the magnetosphere and the ionosphere. One of the SWARM prime scientific objectives is to investigate the influence of these currents, including the ring current and field aligned currents (FAC). To help disentangle their effects, special operations have been designed and coordinated with the ESA Cluster mission. This unique constellation of four satellites enables the measure of these currents at higher altitudes better than any previous mission. The complementarity of these two missions was foreseen at the beginning of the SWARM mission design, about 10 years ago. The 2014 special operations in support of SWARM is in other words a forward-looking idea becoming reality.

We will first briefly recall a few scientific highlights of the Cluster mission, related to the first measure of currents in space by a constellation of four satellites. We will then talk about the on-going 2014 special operations designed and executed in support of SWARM. Finally, we will present future opportunities of special operations that could be executed by Cluster in the years to come.

Presenting Author: Maus S.

Abstract Title: Crustal magnetic field mapping from CHAMP to Swarm

Abstract Topic: First science results

Low orbiting magnetic satellites are ideally suited for mapping the long wavelength part of the crustal field, which is not well determined by stitching together marine and aeromagnetic surveys. Crustal field models from CHAMP were integrated into the World Digital Magnetic Anomaly Map and into continental-scale compilations. Satellite-based crustal field models were also used directly for geological and tectonic studies. CHAMP resolved east-west trending anomalies down to wavelengths of about 260 km. However, it was very challenging to resolve north-south trending anomalies aligned with the satellite orbits. This is due to random offsets between neighbouring tracks caused by un-modelled external fields. Preliminary analysis of Swarm data already shows the tremendous advantage of having a pair of satellites fly side-by side. Besides resolving east-west gradients, individual spacecraft signatures can be separated from natural fields. Despite the high initial altitude of 470 km, crustal field wavelengths down to 400 km, corresponding to spherical harmonic degree 100, are already detectable in the measurements of the lower pair of Swarm satellites. Smaller-scale crustal features will become visible with decreasing orbital altitude over the coming years.

Presenting Author: Park J.

Abstract Title: Low-latitude Plasma Blobs in the Topside Ionosphere as Observed by the Swarm Satellites

Abstract Topic: First science results

Low-latitude topside ionosphere sometimes exhibits localized enhancement of plasma density, which is called plasma blob. Little is known about the spatial structure of the plasma blobs. Previous studies heavily depended on in-situ plasma density measurements, which only gave one-dimensional information of the spatial structure. Although ground-based optical devices and radars also observed plasma blobs, only a few case studies have been reported until now. In this presentation we investigate the spatial structure of plasma blobs using observations of the Swarm constellation. Plasma and magnetic properties of selected examples, which were measured by the Langmuir Probe (EFI) and Vector Field Magnetometer (VFM) on-board Swarm, are discussed in detail. The unique formation flight of the Swarm constellation gives us information on two-dimensional images of plasma blobs. Moreover, exploiting synergetic effects of the different instruments on-board Swarm, we can give reasonable constraints on the three-dimensional shape of plasma blobs.

Presenting Author: Purucker M.

Abstract Title: Estimating the Magnetic Susceptibility of Terrestrial Crust of Continental Affinity

Abstract Topic: First science results

We utilize magnetic models (Xchaos) made from Champ and Orsted data to place constraints on the average magnetic susceptibility and its variability in the continental crust. Our approach estimates the magnetic crustal thickness in a two-step process. The first step utilizes a recent seismic model (Crust1.0) to estimate the thickness of crystalline crust above the Moho, modified in the Andes and the Himalayas to account for the non-magnetic lower crust there. The second step calculates the magnetic field expected from such a layer of crystalline rock assuming that the magnetization is solely induced in the earth's main field by rock of constant magnetic susceptibility, and modifies the starting crustal thickness to bring it into agreement with the Xchaos model. As this is a global model, we remove spherical harmonic degrees less than 15 to account for the core field mask. Because of the dominance of magnetic remanence, and the difficulty of accounting accurately for it, we restrict our attention to the continental crust, in particular to Australia, western North America, and Scandinavia. We perform our simulations with two magnetic susceptibilities, 0.02 and 0.04 SI. The mean crystalline crustal thickness from the seismic model is 42 and 37 km in western North America and Australia, respectively, and the modification with the magnetic data makes little change to the mean crustal thickness, irrespective of whether the magnetic susceptibility is 0.02 or 0.04 SI. However, the modification with the magnetic data does make a significant difference to the standard deviation of the crustal thickness, increasing it by a factor of two in the case of a susceptibility of 0.04, and by a factor of four in the case of a susceptibility of 0.02. The changes to the standard deviation of the crustal thickness are also evident in the Scandinavian data, but the mean crystalline crustal thickness of 45 km is significantly larger than that found from either magnetic model (33 and 30 km). The differences could be due to the presence of magnetic remanence oblique to the present field, or to weaker magnetizations in the crust. We also directly utilize Swarm data from 10 April (Kp<0+) to place bounds on the minimum apparent magnetization required, irrespective of direction, to explain the observations, in an approach pioneered by Parker.

Presenting Author: Van den Ijssel J.

Abstract Title: Precise Science Orbits for the Swarm Satellite Constellation

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems)

ESA's Swarm mission consists of three identical satellites, flying in carefully selected near-polar orbits. Two satellites will fly side-by-side at an initial altitude of 460 km, and slowly descend to around 300 km during the mission. The third satellite remains in a higher orbit of about 510 km altitude. To geolocate the Swarm observations, each of these satellites is equipped with an 8-channel dual-frequency GPS receiver. These instruments deliver high-quality GPS data with a 0.1 Hz data rate, which are used for the precise orbit determination of the satellites. On-board laser retro-reflectors provide the opportunity to validate the orbits computed from the GPS observations.

The computation of Precise Science Orbits (PSO) for the Swarm satellites is part of the activities performed in the Swarm Satellite Constellation Application and Research Facility (SCARF). This consortium of several research institutes is responsible for providing the Swarm Level 2 products. The

Swarm level 2 PSO product nominally consists of a reduced-dynamic and kinematic orbit solutions. A short report describing the quality of the orbits is also included in the product.

A brief overview is given of the adopted orbit determination strategy for both PSO orbits, together with a preliminary assessment of the Swarm GPS receiver performance. Precise orbit determination results for the first months of data are presented, including a validation based on satellite laser ranging measurements.

These preliminary results indicate a consistency level of about 2 cm between the reduced-dynamic GPS-based orbits and SLR observations. The consistency between the reduced-dynamic and kinematic orbits is around 10 cm 3D.

Presenting Author: Vigneron P.

Abstract Title: Inter-satellite assessment of Swarm 1 Hz nominal level 1b scalar data

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems), Presentation of the outcome of the Cal/Val activities

(ASM) provide absolute scalar measurements of the magnetic field with high accuracy and stability on the three satellites of the mission. These measurements are used to produce the 1 Hz nominal level 1b scalar data of the mission, after correcting for all known satellite perturbations. To assess the quality of the final nominal data, we take advantage of data acquired in the early stage of the mission at a time when the three Swarm satellites were still orbiting close to each other (to within typically 100km of each other, or less), and of additional data acquired when a number of attitude manoeuvres were undertaken for various calibration purposes. Data from the three satellites are then compared to each other for consistency, after correction for an a priori main field model (to remove first order differences expected from the main field gradient, given the slightly different orbits of the three satellites). This reveals an overall excellent agreement, particularly when all satellites are in their nominal attitude. Under certain manoeuvre circumstances, however, slight (less than 1nT) systematic differences are found, which are still under investigation. Results from such on-going investigations will be presented and discussed. These will hopefully lead to further improvements in the way 1 Hz nominal level 1b scalar data are processed.

Presenting Author: Whaler K.

Abstract Title: Core Surface Flows that Explain Rapid Observatory Secular Variation Changes

Abstract Topic: Plans for exploitation projects

Based on a new way of calculating observatory monthly means, reducing external field contamination and providing much less noisy estimates, we invert annual differences of monthly means for advective core surface flows. The surface flows were obtained assuming the flow was steady over three consecutive months to ensure uniqueness, and were spatially regularised. Observatory data were inverted directly, rather than deriving the flow from secular variation (SV) spherical harmonic models. The main field was specified by the CHAOS-4 model. Data from up to 128 observatories between 1997 and 2013 were used to calculate 185 flow models from the ordinary and revised monthly means, for each possible set of three consecutive months.

We incorporated correlations between components by using 3x3 data covariance matrices for each observatory, and minimised a two-norm measure of data misfit and flow smoothness. The models fit the data adequately, and are able to follow rapid changes in SV. Some of these changes in the ordinary monthly mean data first differences are likely to be from external field contamination, and therefore we prefer to work with revised monthly mean data. Despite being based on the rather sparsely distributed observatories, resolution matrices for the inversions suggest the large-scale coefficients of the flow are resolved. The situation should improve further for inversions of the dense Swarm satellite data. We find the fit to the data is not seriously degraded if we suppress temporal changes in all but the odd degree, zero order, toroidal flow coefficients that represent torsional oscillations. However, we cannot fit the data adequately with temporal variability consisting only of torsional oscillations. Whereas the flow coefficients of the original flow change quite rapidly, for the temporally constrained flow the variability is much more subtle, yet the flow is still able to predict the rapid SV changes.

Poster Abstracts

Presenting Author: Aakjær C. D.

Abstract Title: Modelling the Magnetic field of the Polar Electrojet

Abstract Topic: Plans for exploitation projects

Modern geomagnetic reference models give a very good description of the Earth's magnetic field, including its contributions from the core and crust at low and mid-latitudes. However, in the polar region, the ionospheric current system causes irregular contributions to the magnetic field, not included in present reference models, hampering applications such as directional drilling.

The spherical elementary current systems (SECS) method introduced by Amm (1997) has been used here to model the polar electrojet. The method is an inverse modelling technique, able to give a full ionospheric current distribution along with the field aligned currents from sets of two basic functions in spherical coordinates, a divergence free and a curl free part. So far a 1D version of the method (independent of longitude) has been implemented, as presented by Juusola et al (2001), which is very convenient when working with satellite data such as CHAMP and Swarm. We have extended the method of Juusola et al (2001) to include an expression for the currents induced within the Earth.

Expressing the magnetic field vector as a scalar potential provides a means of account for these secondary, Earth-induced, contributions.

References:

Amm (1997), Ionospheric elementary current systems in spherical coordinates and their application, Journal of geomagnetism and geoelectricity, 49, 1997.

Juusola et al (2001), One-dimensional spherical elementary current systems and their use for determining ionospheric current from satellite measurements, Earth Planets Space, 58, 2006.

Presenting Author: Archer W.

Abstract Title: Ion Thermalization at 500 km

Abstract Topic: First science results

The Electric Field Instruments (EFIs) aboard the Swarm satellites carry a new generation of thermal ion detector. A pair of these detectors mounted perpendicular to one another aboard each of the three satellites measures the local three dimensional ion velocity distributions. The EFIs primary function on Swarm is to measure local electric fields to provide corrections for magnetometer measurements being made on the satellites; however their design also makes them ideal for measuring ion temperature anisotropies.

For the first six weeks of the Swarm mission (launched in November 2013) the three satellites were in similar polar orbits, with satellites spaced 60 and 90 seconds apart. This configuration is ideal for measuring temporal variations in plasma conditions as all three satellites pass through the same regions. This study will focus on temperature anisotropy and temporal evolution of heated ions measured by the Swarm satellites at 500 km altitude.

Presenting Author: Balasis G.

Abstract Title: The Time-Frequency Analysis (TFA) Tool: a Wavelet-Based Set of Tools Capable for Automated Detection of Artificial and Natural Signals in the Magnetic and Electric Field Measurements of Swarm

Abstract Topic: Presentation of the outcome of the Cal/Val activities

A multitude of successful space missions over the past 15 years has provided the scientific community with a bounty of high-quality data on the magnetic and electric fields surrounding our planet. This data pool is now further enriched by the measurements of the Swarm mission.

Here we report on the application to Swarm measurements of a recently developed suite of wavelet-based algorithms suitable for the analysis of multi-instrument multi-satellite and ground-based measurements with the aim to detect ULF wave events in tri-axial satellite magnetic field data and distinguish them from Equatorial Spread F (ESF) events, pre-processing errors or instrumental noise in an automated way. The time-frequency spectrogram forms the basis for the automated ULF wave detection and is used along with statistics derived from the time series data, which convey information about the nature of the signal. The first step consists of isolating short segments of the time series data where the wavelet power exceeds a predefined threshold. These are classified as wave “events”, “false-positive” signals and “non-events” depending on whether a series of criteria are successfully met.

Presenting Author: Baykiev E.

Abstract Title: Forward Modelling of the Fennoscandian Lithospheric Field Using Spherical Prisms

Abstract Topic: First science results, Presentation of user projects and their initial results

We show the first results of a sensitivity analysis used to determine if and how induced and remanent magnetization can be distinguished in magnetic data from the Swarm satellite mission. The Swarm satellite magnetic data have higher resolution (to 200km wavelength) and accuracy than previous satellite missions, which makes them complimentary to airborne magnetic surveys.

However, calculations at satellite level require a spherical modelling approach. We present a newly developed software that allows fast calculation of the crustal magnetic field. The crustal model is represented as a set of spherical prisms, tesseroids. Synthetic models, global and local tests using the geometry of CRUST1.0 show that our model approach leads to similar results as alternative modelling techniques (global or local), but have a higher precision.

This approach is applied to Fennoscandia, where we try to validate the effect of induced and remanent magnetization in magnetic data at the height of satellites and airborne surveys.

As the first example of this approach we are going to show an initial model based on petrophysical maps of Norway and Scandinavia (susceptibility and total magnetization) and how variations of the normal Earth's magnetic field affect the lithospheric field in the modelled region.

Presenting Author: Beggan C.

Abstract Title: Forecasting Secular Variation from CHAMP to Swarm

Abstract Topic: First science results

Models of the main field and its secular variation (SV) have been relatively poorly constrained without global high quality vector satellite data during three year period from the de-orbiting of CHAMP to the launch of Swarm. We compute SV of the main magnetic field between 2010.5 and 2014.0 using the latest BGS main field model (see accompanying poster) based on the final data from the CHAMP mission and the first data from Swarm.

The ability to generate forecasts of sufficient accuracy for SV over a five year period is still an active area of research. We compare the forecasts of the World Magnetic Model and International Geomagnetic Reference Field as both revised in late 2009 to the latest Swarm main field model to establish how close each one is to the 'true' variation of the field over the past four years.

Presenting Author: Bi Y.

Abstract Title: Detecting Anomalies from Satellite and Ground Based Electromagnetic Data Using Data Analytics Approaches

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems)

This work will report the progress of the project supported by the Dragon 3 programme, which is aimed to developing viable methods and techniques for detecting anomalies from space and terrestrial electromagnetic data that are observed by the SWARM satellite and the network of the Control Source Extremely Low Frequency (CSELF) in China and investigating the correlation between anomalies and earthquakes. Presently two initial algorithms for change detection have been developed and implemented. The first algorithm is developed on the basis of the wavelet theory. It will be applied to calculate wavelet maxima from electromagnetic data in various scales. The resulting maxima values are aligned on spatio-temporal axes into a collection of curves that are viewed as a representation or patterns of change characters reflected in the data sources. The second one is based on the Martingale method that is concentrated on detecting individual isolated change points within the electromagnetic data. This method is inspired by the observation that any changing points within the neighbourhoods of an isolated change point have less influence in the calculation process of detecting other change points. The preliminary evaluation for both algorithms has been carried out on the four years NOAA Outgoing Longwave Radiation (OLR) data and the investigation into the correlation the changes detected and the Wenchuan and Puer earthquakes has also been conducted. Currently we are adapting the algorithms to analyse the first phrase of SWARM data and report our preliminary results in the workshop.

Presenting Author: Bogdanova Y. V.

Abstract Title: Field Aligned Currents in the Cusp: Research Opportunities with Swarm Mission

Abstract Topic: Plans for exploitation projects

Field-aligned currents (FACs) play a fundamental role in the solar wind energy and plasma transfer to the magnetosphere and ionosphere, and the spatial and temporal variations of various FAC systems are under active investigation. Here we present observations of the field-aligned currents in the mid-altitude cusp by 4 Cluster spacecraft and discuss their filamentary structure and variability for different IMF conditions and at different multi-spacecraft separation scales. In addition, we show and analyse an event with the cusp field-aligned currents observed by CHAMP as an example of future FAC observations from the Swarm mission. We then discuss the opportunities for studying cusp field-aligned currents using the data coming from Swarm mission, which will provide multi-point measurements of the magnetic field and plasma at low polar orbit. We will consider how such observations can enhance our knowledge of filamentary structure and time variability of cusp field-aligned currents and what type of conjunctions between Cluster and Swarm would facilitate research of the cusp, Region 0 and Region 1 current systems.

Presenting Author: Brocco L.

Abstract Title: Swarm's Absolute Scalar Magnetometer experimental vector field measurements: first conclusions from comparisons with 1 Hz nominal Swarm Level1b vector data

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems), Presentation of the outcome of the Cal/Val activities

Swarm’s Absolute Scalar Magnetometers (ASM) provides absolute scalar measurements of the magnetic field with high accuracy and stability on the three satellites of the mission. These are used to produce the 1 Hz nominal Swarm Level1b scalar data and to calibrate the 1 Hz nominal Swarm Level1b vector data. In addition, and on an experimental basis, these ASM instruments can also, and simultaneously, provide independent vector field measurements. These appear to be of very stable quality, with no apparent biases, and can thus be used for comparison with readings from the Vector Field Magnetometer (VFM, located some distance away along the boom and used to produce the nominal

Swarm Level1b vector data) for quality crosschecks, possible detection of undesired satellite signals, as well as assessment of the stability of the mechanical link between both instruments. Here, we will describe how such crosschecks and comparisons, which imply using appropriate synchronization and alignment procedures, can be carried out, and present conclusions from such comparisons. Most encouraging is the fact that the mechanical link between the ASM and VFM instruments appears to be very stable on all three satellites, suggesting that further more detailed comparisons could be made between ASM and VFM vector data to help investigate consistency issues that may remain between 1 Hz nominal Swarm Level1b vector and scalar data (e.g., possible time-varying differences between modulus of the vector data and the scalar data, even after implementation of the nominal VFM calibration procedure). Results from such on-going investigations will be presented and discussed.

Presenting Author: Canet E.

Abstract Title: Data Assimilation into a Model of Earth's Core Rapid Dynamics

Abstract Topic: Presentation of user projects and their initial results

The ESA-Swarm mission is extending more than a decade of continuous monitoring of the Earth's magnetic field from both space and ground network observatories. Thanks its unique design, the Swarm mission will help a better separation of the core field from the other sources of magnetic field.

The improved knowledge of the core magnetic field can translate into improved understanding of the underlying core processes if the data and models of core dynamics can be combined in an efficient way, with data assimilation.

Data assimilation is a methodology to combine a model of the dynamics of a system and a dataset of the system.

In that framework, we propose to use a quasi-geostrophic model of core dynamics. The quasi-geostrophic assumption is based on the predominance of rotation forces over magnetic forces at timescales of decades to centuries. It is tailored to describe the short timescale physics associated with the rapid changes of magnetic field revealed by satellite data.

We present the model and its associated linear dynamics. Such a system supports two classes of quasi-geostrophic modes: fast, primarily hydrodynamic, inertial modes with period related to the rotation time scale and slow, primarily magnetic, magnetostrophic modes with much longer periods that decay due to magnetic dissipation.

Presenting Author: Civet F.

Abstract Title: Toward a New Swarm-Based Global Electromagnetic Picture: Results from the Simultaneous Use of Ørsted and CHAMP Data

Abstract Topic: Presentation of user projects and their initial results

The electromagnetic properties of the largest part of the Earth's mantle (down to about 2000 km) can be better characterized thanks to the magnetic field measurements provided by the recently launched Swarm satellite mission. Here we present a study using both Ørsted and CHAMP measurements as a unique equivalent before the awaited Swarm ones. Instead of the usual single-satellite approach, which generally assumes a dipolar geometry for the external field, we solve the global electromagnetic induction problem by extending the single-satellite procedure to the multi-satellite case. In addition we use a new proxy for the temporal variability of the external source derived from aσ indices and computed as a function of magnetic local times. The results obtained up to degree three and for three independent one-year-long time series, demonstrate that this new proxy leads to an improvement of both spatial (to high latitude, $|\theta| > 50°$), and temporal resolutions, especially at short periods (between 12h to 10 days). These new results are compared to previous studies to show the possibilities offered by this new approach.

Presenting Author: Crespo Grau R.

Abstract Title: Early results from Swarm's Absolute Scalar Magnetometers burst mode

Abstract Topic: Presentation of the outcome of the Cal/Val activities, Presentation of user projects and their initial results, Plans for exploitation projects

Swarm's Absolute Scalar Magnetometers (ASM) provides absolute scalar measurements of the magnetic field with high accuracy and stability on the three satellites of the mission. These ASMs nominally run at 1 Hz. But they can also run at 250 Hz frequency using a so-called "burst" mode. This possibility has been taken advantage of during commissioning, the burst mode having been run simultaneously on all three satellites over several days. These burst mode sessions were driven by the engineering need to explore the high frequency spectral content of the signal measured by the ASMs, to identify issues that could affect not only the nominal 1 Hz scalar data but also the 1 Hz vector data that the ASM simultaneously deliver on an experimental basis. Two unexpected issues have been identified, one related to the activation of a piezo-electric motor built in the instrument, the other related to the heaters used to keep the instruments within operating temperature range. Fortunately, these issues do not affect the nominal 1 Hz scalar data of the mission, and their impact on the 1 Hz experimental vector data can be handled. These burst mode data can now be used to look for meaningful high frequency geomagnetic signals.

Presenting Author: Dahle C.

Abstract Title: Orbit and Gravity Field Solutions from Swarm GPS Observations - First Results

Abstract Topic: First science results, Release of Swarm Level 1 data products, Presentation of user projects and their initial results

(Although ESA's Earth Explorer Mission Swarm is primarily dedicated to measure the Earth's magnetic field, it may also serve as a gravity field mission. Equipped with GPS receivers, accelerometers, star-tracker assemblies and laser retro-reflectors, the three Swarm satellites are potentially capable to be used as a high-low satellite-to-satellite tracking (hl-SST) observing system, following the missions CHAMP (first single-satellite hl-SST mission), GRACE (twin-satellite mission with additional ultra-precise low-low SST) and GOCE (single-satellite mission additionally equipped with a gradiometer). GRACE, dedicated to measure the time-variability of the gravity field, is the only mission still in orbit, but its lifetime will likely end before launch of its follow-on mission GRACE-FO in August 2017 primarily due to aging of the on-board batteries after meanwhile more than 12 years of operation.

Swarm is probably a good candidate to provide time-variable gravity field solutions and to close a potential gap between GRACE and GRACE-FO. Consisting of three satellites, Swarm also offers to use inter-satellite GPS-derived baselines as additional observations. However, as of today it is not clear if such information will substantially improve the gravity field solutions. Nevertheless, the properties of the Swarm constellation with two lower satellites flying in a pendulum-like orbit and a slightly differently inclined third satellite at higher altitude still represent a unique observing system raising expectations at least compared to CHAMP derived time-variable gravity field solutions.

Whatever processing method will be applied for Swarm gravity field recovery, its success strongly depends on the quality of the Swarm Level 1b data as well as the quality of the derived Swarm orbits. With first Level 1b data sets available since mid of May 2014 (excluding accelerometer data), we present some first results for Swarm orbits and gravity field solutions. Our results are based on at least one month of Swarm Level 1b data and are compared to results from other missions based on the same amount of data and processing methods.

Presenting Author: Echim M.

Abstract Title: Electric, Magnetic and Ionospheric Survey of Seismically Active Regions with SWARM

Abstract Topic: Plans for exploitation projects

We present a project devoted to the scientific exploitation of SWARD data. SWARM multi-point measurements of the magnetic and electric field, of the electron temperature and density in the ionosphere will provide unique opportunities to study in-situ and remotely the electromagnetic and plasma variability due to ionospheric forcing from above and below. The project “Electric, Magnetic and Ionospheric Survey of Seismically Active Regions with SWARM (EMISSARS)” focus on coordinated studies between SWARM and ground based observatories to survey electromagnetic and ionospheric variability at medium latitudes and look for possible correlations with the seismic activity in central Europe. The project is coordinated by the Institute for Space Sciences (INFLPR-ISS) and the National Institute for Earth Physics (INFP) in Bucharest, Romania. In addition to SWARM data the project benefits from support of dedicated ground based measurements provided by the MEMFIS network coordinated by INFP, the MM100 network of magnetic observatories coordinated by the Eotvos Lorand Geophysical Institute (ELGI) in Budapest, Hungary. Seismic data are provided by INFP and the European Mediterranean Seismological Centre.

The mission of the project is to monitor from space and from ground the ionospheric and electromagnetic variability during time intervals prior, during and after seismic activity. In the initial phase we plan to investigate (i) the seismic active regions of the central Europe and (ii) in regions unaffected by the seismic activity. Later on, other seismically active regions may be targeted. The scientific objectives of the project are: (1) Observation of electric, magnetic and ionospheric (electron temperature, density) variability in the ionosphere above or in the close vicinity of seismic active regions, in conjunction with ground based observations from dedicated networks; (2) Investigation and modelling of the coupling between the litosphere - atmosphere - ionosphere, during Earthquakes; (3) Quantitative nonlinear analysis of anomalous magnetic events detected on ground and in space before, during and after Earthquakes. The methodology includes innovative methods of analysis like : (i) Power Spectral Density (PSD) of electric, magnetic, lithospheric signal, (ii) Probability Distribution Functions (PDFs) at various scales from multi-spacecraft statistical ensembles, (iii) auto and cross-correlation analysis of magnetic field and ionospheric variables for search of coherent structures, (iv) numerical modelling of the litosphere-atmosphere-ionosphere coupling based on the current continuity.

Presenting Author: Encarnacao J.

Abstract Title: Combination of Swarm's Uncalibrated Accelerometer Data with POD-Based Accelerometry

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems)

ESA's Swarm satellites aim to measure the geomagnetic field with unprecedented accuracy. The satellites are also equipped with highly-sensitive tri-axial accelerometers with the purpose of measuring the non-gravitational forces, in the context of thermospheric neutral density studies. The data collected by the accelerometer during the commissioning phase are affected by jumps and biases and display heavy temperature dependence. This makes it difficult to use traditional calibration methods, such as employed for CHAMP and GRACE accelerometer data. A possible solution is to discard the frequency band of the accelerometer data where these artefacts are located. The jumps in the data seem to be associated with very high-frequencies, whereas the biases and temperature effects are occurring mainly at low frequencies. By means of a band-pass filter, significant information might be efficiently extracted from the measured accelerations without resorting to complicated and specialized calibration techniques. To compensate for the loss of low-frequency information, synthetic accelerations will be derived where the filtered accelerometer data are augmented with the accelerations derived from POD. First results of the proposed method will be presented, where these synthetic accelerations will be compared against accelerations predicted by models.

Presenting Author: Finlay C.

Abstract Title: Data Error Covariances for Satellite Magnetic Data

Abstract Topic: Plans for exploitation projects

In geomagnetic field modelling, it is commonly assumed that satellite magnetic data errors are uncorrelated in both time and space. This results in a diagonal data error covariance matrix, thus simplifying the inversion procedure, but it ignores correlations due to any sources have not been modelled. If full advantage is to be taken of Swarm data, it is clear that better account should be taken of such spatially and temporally correlated errors, through an improved data error covariance matrix.

As one illustration of the type of problem that can arise due to correlated satellite data errors, we show how attempts to build very high time resolution field models with {O} rested, CHAMP and SAC-C data suffer from spurious oscillations in specific components, once the standard temporal regularization is relaxed. Similar problems hamper attempts to model the lithospheric field at very high spatial resolution. In a step towards better understanding and remedying this situation, we document the correlation of residuala (between CHAMP magnetic data and the CHAOS-4 field model) as a function of both time and of quasi-dipole latitude. Techniques to parameterize the form of these correlated errors and their use (via data covariance matrices) in practical inversion schemes will be discussed. The success of future assimilation of Swarm magnetic data into numerical models of core dynamics, as well as rigorous hypothesis testing with field models may ultimately be reliant on access to suitable data error covariance matrices.

Presenting Author: Foerster M.

Abstract Title: The Role of the Magnetic Field Hemispheric Asymmetry for the High-latitude Plasma Drifts and Upper Atmosphere Neutral Winds

Abstract Topic: Presentation of user projects and their initial results, Plans for exploitation projects

The non-dipolar portions of Earth's main magnetic field constitute substantial differences between the geomagnetic field configurations of both hemispheres. This involves in particular different magnetic field flux densities and pattern structures in the opposite polar regions and differing offsets (factor 2) of the invariant poles with respect to the rotation axis of the Earth. This asymmetry has substantial implications for the coupled system of magnetosphere-ionosphere-thermosphere (M-I-T) under the influence of external drivers. Recent observations have shown that the ionospheric/thermospheric response to solar wind and IMF dependent processes in the magnetosphere can be very dissimilar in the Northern and Southern Hemisphere. We present statistical studies of both the high-latitude ionospheric convection and the upper thermospheric circulation patterns obtained from the electron drift instrument (EDI) on board the Cluster satellites and the accelerometer on board the CHAMP spacecraft, respectively. Physical-numerical model simulations of the M-I-T system using both symmetric dipole and realistic (IGRF) geomagnetic field configurations confirm the importance of the hemispheric differences for the plasma and neutral wind dynamics. The survey of both the numerical simulation and the statistical observation results show some prominent asymmetries between the two hemispheres. The Swarm mission will considerably augment our observational basis and provide valuable data for further detailed studies of the North-South asymmetries in plasma drift and neutral wind dynamics.

Presenting Author: Gerzen T.

Abstract Title: Modelling of the Ionosphere and Plasmasphere with SWARM

Abstract Topic: Plans for exploitation projects

Plasmaspheric electron content is, beyond the ionosphere as major source, a significant contributor to the overall TEC budget affecting GNSS signals. So the plasmasphere can contribute up to half or even more of the GNSS range errors. GNSS measurements on-board SWARM and in-situ data of the SWARM mission together with ionospheric measurements, available on-board of the LEO-satellites GRACE, TerraSAR- and Tandem-X, offer a unique opportunity for more comprehensive multi-sensor data driven modelling of the global 3D topside ionosphere and plasmasphere. Especially the specific SWARM satellite constellation facilitates a deeper analysis of the space weather related changes and disturbances in the geo-plasma and a detailed studying of solar-terrestrial relationship during severe space weather events. Most notable in the regions with pure ground-based GNSS data coverage, the contribution of the LEO GNSS and ionospheric radio occultation data for monitoring the ionospheric impact on transionospheric radio systems is of particular interest.

At DLR Neustrelitz, Germany, GPS measurements recorded on-board the LEO-satellite CHAMP were used since 2001 to reconstruct the topside ionosphere and plasmasphere electron density distribution in the vicinity of the CHAMP orbit plane. In this presentation we present results showing the potential of these reconstructions for analysing the geo-plasma, but at the same time illustrating the need of additional data with better observation geometry to establish an appropriate data base for the modelling of the complete plasmasphere. For this purpose, comparisons are made between the CHAMP reconstructions and electron densities derived from passive radio wave observations by the IMAGE RPI instrument for years 2001 till 2005.

The comparison results indicate that an improvement, compared to the background model, can be achieved by CHAMP data assimilation. The improvement is especially visible in the L-shell region below 3. However, for the region around the plasmapause, systematical electron density underestimations of the background model w.r.t. the IMAGE data are detected. The rather limited CHAMP data coverage and the degraded observation geometry at these high altitudes seem to be not sufficient for complete compensation of this underestimation during the assimilation procedure. We expect that SWARM data, in particular by utilizing the formation flight capabilities of the SWARM mission, will considerably improve the situation and will further complete our topside ionosphere/plasmaspheric studies based on CHAMP data so far.

Presenting Author: Gillet N.

Abstract Title: Stochastic Forecast of the Geomagnetic Field

Abstract Topic: Presentation of user projects and their initial results, Plans for exploitation projects

We present a new method to forecast the geomagnetic field probability density function. It is based on a stochastic model for the flow in the Earth's outer core and the radial induction equation at the core-mantle boundary. We make use of an Ensemble Kalman filter with an augmented state approach to account for the time-correlated model errors associated with the unresolved main field at small length-scales. We benchmark our algorithm with a synthetic experiment, where we show our ability to reasonably retrieve the core flow, and to provide reasonable estimates of the probability density function for the main field and its secular variation. This method is then applied to the COV-OBS geomagnetic field model derived from observatory and satellite observations. We discuss perspectives for the production of IGRF models.

Presenting Author: Hamilton B.

Abstract Title: A new algorithm for rapid magnetospheric field modelling using Swarm data

Abstract Topic: First science results

We present an algorithm for per-orbit modelling of the Earth's large scale vector magnetospheric field using satellite data, with potential for near real-time use.

The method has been implemented as part of the "Satellite Constellation Application and Research Facility" (SCARF) for the ESA Swarm mission, making use of the constellation's unprecedented spatial coverage. The magnetospheric field model will be released daily as part of the Level-2 product range. As well as addressing scientific interests in the external field of the Earth, this vector magnetospheric field model could be of use in space weather applications, where measures of geomagnetic activity are required, and as inputs to other magnetic field modelling studies. Unlike magnetospheric field indices, such as the 'scalar-valued' Disturbance Storm Time (Dst) index, the algorithm presented here attempts to preserve the absolute level of the field by avoiding post-fitting a baseline. Instead, it takes as input the residuals after removing a priori models of the non-magnetospheric fields. The algorithm is robust, operates automatically and has the potential to be run in near real-time if required.

We present models produced using the first five months of Swarm data. We compare these models with the observatory-based Dst and Vector Magnetic Disturbance (VMD) indices and comment on their consistency.

Early Swarm data contains many gaps in coverage. Whilst this is likely to be a temporary challenge for the initial models, it also provides an excellent test of their robustness both as scientific products and for their production via an automated processing chain. We comment on this robustness and its impact on model provision.

Early in the mission, the Swarm satellites are in similar orbits but over the course of the mission, the upper and lower-pair will diverge in local time. We compare models produced from individual satellites for consistency early in the mission and, although the separation so far is quite small, we look for early signs of local-time dependent differences in the modelled field.

Presenting Author: He M.

Abstract Title: Comparison of Gradient and FAC Estimation Techniques for Swarm

Abstract Topic: First science results, Presentation of the outcome of the Cal/Val activities, Presentation of user projects and their initial results

The constellation of Swarm satellites allows estimating spatial gradients and field-aligned currents (FACs) using differences of measurements at two or, occasionally, even three points in space. This presentation compares a recently developed least squares (LS) gradient estimator with existing finite difference (FD) schemes for quasi-static structures. The planar gradient is constructed from observations along the trajectories of the pair of Swarm spacecraft on close orbits. To facilitate error analyses and consistency checks, and to show how arbitrary combinations of planar gradient estimators and constraint equations for the out-of-plane derivative can be formed, the two-spacecraft LS and FD techniques and a three-spacecraft LS scheme are integrated in a common framework. We study the accuracy of LS and FD planar gradient estimators, discuss the implications of imperfect constraint equations for error propagation, and address the effects of sub-scale structures. The two-spacecraft LS scheme and three different types of constraints are applied to Cluster FGM observations of a planar and essentially force-free plasma structure in the interplanetary magnetic field.

Presenting Author: Heilig B.

Abstract Title: Monitoring the plasmapause by SWARM

Abstract Topic: Plans for exploitation projects

Recently a new method for monitoring the plasmapause location in the equatorial plane was introduced based on magnetic field observations made by the CHAMP satellite in the topside ionosphere (Heilig and Lühr, 2013). Related signals are medium-scale field-aligned currents (MSFAC) (some 10km scale size). The method is planned to be applied to the SWARM constellation. The signals related to the plasmapause on the dayside are often appear mixed with other phenomena (e.g. ULF waves). Now making use of the special constellation of SWARM we will be able to discriminate temporal and spatial variations and detect the dayside plasmapause more clearly.

We plan to build an empirical plasmapause model, similar to the CHAMP-based model (Heilig and Lühr, 2013). The model will be validated by means of ground (EMMA magnetometer network) plasmapause observations, as well as by the in-situ plasma observations of the Van Allen Probes.

Heilig, B., and H. Lühr (2013) New plasmapause model derived from CHAMP field-aligned current signatures, Ann. Geophys., 31, 529-539, doi:10.5194/angeo-31-529-2013

Presenting Author: Heilig B.

Abstract Title: ULF waves in the topside ionosphere

Abstract Topic: First science results

Different types of ULF waves (dayside compressional Pc3s, FLRs, night side Pi2s, etc) have been successfully identified in the topside ionosphere. ULF observations in this region can help us to understand the wave structure in the magnetosphere, wave propagation, and also the effects of the ionosphere (transmission, reflection, mode conversion).

Because of the fast orbiting of the LEO satellites Fourier analysis is not applicable, special techniques are needed to resolve ULF signals. We use the wavelet analysis for spectral analysis. ULF waves are interpreted in a mean field aligned coordinate system. LEO observations are compared to ground observations along the EMMA magnetometer chain.

The first results clearly show that the quality of SWARM magnetic observations is high enough for successful ULF wave detection. We present the first examples of ULF events (dayside compressional Pc3s, night side Pi2s) detected by the SWARM trio. Our preliminary results confirm that the coherence length of compressional Pc3s is several thousands of kms on the dayside. We also demonstrate how the mission can contribute to our growing knowledge on ULF wave phenomena.

Presenting Author: Holzrichter N.

Abstract Title: Geophysical Application of GOCE Gradients and SWARM Magnetic Data. Towards a Consistent 3D Lithospheric Model

Abstract Topic: Plans for exploitation projects

The thorough understanding of the solid Earth system is an essential step towards deciphering the link between the dynamic processes in the Earth system and the near-surface processes that lead to geohazards, the rise of mountains or the accumulation of natural resources. The global availability of potential field data provided from GOCE and SWARM in combination with seismological models makes it possible to establish consistent, homogeneous 3D models of the lithosphere. All these data sets have due to their specific characteristics a sensitivity to different parts of crust and upper lithospheric mantle, which is exploited here.

Several problems have to be solved to allow such a comprehensive model. First, algorithms for the interpretation of satellite data for a spherical Earth have to be developed, as well as a set-up that allows integrating different geophysical models. Rigorous sensitivity analysis will be applied to test the reliability and resolution of lithospheric structures estimated from magnetic data, the density distribution in the lower crustal und upper mantle from gravity gradients and the deep lithosphere and sub-lithospheric mantle from the gravity field and geoid.

The estimates of magnetic and density sources for the lithosphere will be used to model the temperature and composition in the lithosphere and to compare and validate the lithospheric model with seismological models. A key interest is the possible improvement of seismological methods by integration of other data sets with respect to resolution and accuracy.

Finally, this work will provide a global model of the 3D lithosphere, characterized by temperature, velocity and density that indirectly describe composition. The model will further be used to improve estimates of the gravity field/geoid related to sub-lithospheric processes in the dynamic mantle. Estimates of dynamic topography will be validated to overcome the bias by simplified lithospheric models.

Presenting Author: Hoque M.M.

Abstract Title: A New Approach for Receiver Bias Estimation and TEC Calibration for SWARM-GPS Paths

Abstract Topic: First science results

The GPS receivers on-board three identical SWARM satellites provide dual-frequency carrier-phase and code-pseudorange measurements primarily for orbit determination. Since the ionosphere is a dispersive medium, i.e. refraction effects are frequency dependent. Hence, by combining measurements at two or more frequencies the propagation delay or ionospheric total electron content (TEC) can be estimated along the SWARM-GPS paths. The phase derived TEC is precise and smooth but biased by an unknown phase ambiguity constant whereas the code derived TEC is not ambiguous but noisy and less precise. Therefore, we use the low-noise carrier phase derived relative TEC to smooth the code-derived relative TEC. However, the differential carrier phase and code measurements are biased by receiver and satellite instrumental delays. Here we present a new method for bias estimation of GPS receivers installed on board the SWARM satellites for slant TEC calibration. Used are the daily estimates of GPS satellite biases that are publicly available from the Centre for Orbit Determination in Europe (CODE) in Bern. Additionally, high quality CODE post processed vertical TEC maps are used together with a multi-layer mapping function approach to initialize TEC for the highest elevation angle ray-path in the SWARM-GPS connected arc. An exponential decay of electron density with altitude is used to model the plasmaspheric electron content above the SWARM satellite height. We successfully tested and validated the method for the GPS receiver bias estimation on board COSMIC satellites. Although the SWARM satellites (~460 - 530km) fly far below of the orbit of the COSMIC satellites (~700 - 800km) the initial investigation shows that the method can also be applied for receivers on-board lower satellite orbit height due to usage of actual vertical TEC maps and advanced mapping function approach.

Presenting Author: Jault D.

Abstract Title: On the high frequency variations of the main Earth’s magnetic field screened out by the electrically conducting lower mantle

Abstract Topic: Presentation of the outcome of the Cal/Val activities

Present investigations of the Earth's core magnetic signal are limited to frequencies f less than about 0.25 cycle per year. Hopefully, magnetic data collected from the Swarm constellation of satellites will enable us to extend these studies to higher frequencies. The final limitation on such analyses will be set by the electrical conductivity of the lower mantle, which screens out very high frequency magnetic variations. Future attempts at assimilating magnetic field data in models of Earth's core dynamics will thus require information on the mantle effects. Treating the mantle as a linear time-invariant filter for core signals, we only need to estimate either the impulse response function or the frequency response function of the filter.

In order to investigate how the mantle filters the core signals from data recorded above the Earth's surface (the output), it is necessary to have knowledge about the time spectrum of the magnetic field at the core surface (the input). The spectral density function S(f) for the second time derivative of the magnetic field coefficients scales approximately as f0 in the frequency range for which the mantle is unimportant. In the absence of any other information, we cannot do better than extrapolating the scaling law S (f) ~1 to higher frequencies. Considering different radial profiles for the mantle electrical conductivity, the frequency response function of the mantle filter can be compared to the function estimated in the low frequency limit by Backus (1983). It turns out that the low frequency approximation severely overestimates the screening by the mantle of high frequency signals. This gives us hope to find evidence of high frequency core signals in Swarm magnetic field data. These conclusions, however, rest on the hypothesis that magnetic field fluctuations of origin in the mantle do not enter the core, on account of its high conductivity. This approach neglects the possible dynamical role (e.g. emission of waves) of the core surface electrical currents that arise in the presence of varying fields external to the core.

Finally, there are in all probability great variations of the electrical conductivity at the base of the mantle. Any information on the lowermost mantle conductivity obtained from the study of magnetic signals emanating from the core would help to constrain scenarios concerning the formation of the core and of the deep mantle or about on-going chemical reactions at the CMB.

Presenting Author: Knipp D.

Abstract Title: Comparison of Low Earth Orbit Magnetometer Data

Abstract Topic: Presentation of the outcome of the Cal/Val activities, Plans for exploitation projects

Introduction: We provide a retrospective assessment and comparison of magnetometer data from The ST5 spacecraft constellation and two Defence Meteorological Satellite Program spacecraft (DMSP F15 and F16) orbiting during March 22 – June 21, 2006 when recurring high-speed streams caused regular geospace disturbances. The ST5 spacecraft were in a 300 km x 4500 km orbit while the DMSP spacecraft were in near circular orbit at ~ 850 km.

Methods: To facilitate the comparisons we propagated the DMSP orbits to provide location data each 1-sec vs the previously available 1 min location data. We developed an improved conjunction-finding method, which works in concert with the Modified Apex coordinate system. We also modernized and reimplemented a fast method for baseline removal for the DMSP satellites that is applicable to active geomagnetic conditions.

Results: After putting the data in a common reference frame, with observations mapped to 110 km, we find excellent agreement between magnetic perturbations in 277 conjunctions between DMSP and ST5. The median magnitude discrepancy is ~ 65 nT for space/time conjunctions within 3° and 90 sec.

Discussion and Conclusions: The ST5 and DMSP magnetic perturbations are being prepared for re-release into a virtual observatory. The methodology reported here provides a 'path forward' in terms of comparing on-orbit electromagnetic field data from multiple spacecraft. We anticipate that these methods will be useful for future comparisons with SWARM data.

Presenting Author: Kother L.

Abstract Title: An Equivalent Source Method for Modelling the Global Lithospheric Magnetic Field

Abstract Topic: Plans for exploitation projects

We present a new technique for modelling the global lithospheric magnetic field at Earth's surface based on the estimation of equivalent potential field sources. As a demonstration we show an application to magnetic field measurements made by the CHAMP satellite during the period 2009-2010 when it was at its lowest altitude and solar activity was also remarkably quiet. All three component vector field data are utilized at all latitudes. Estimates of core and large-scale magnetospheric sources are removed from the measurements using the CHAOS-4 model. Quiet-time and night-side data selection criteria are also employed to minimize the influence of the ionospheric field. The model for the remaining lithospheric magnetic field consists of magnetic point sources (monopoles) arranged in an icosahedron grid. The corresponding source values are estimated using an iteratively reweighted least squares algorithm that includes model regularization (either quadratic or maximum entropy) and Huber weighting. Data error covariance matrices are implemented, accounting for the dependence of data error variances on quasi-dipole latitudes and covariances between the vector field components due to unmodelled sources. Results show good consistency with the CHAOS-4 and MF7 models for spherical harmonic degrees up to n = 95. Advantages of the equivalent source method include its local nature, allowing e.g. for regional grid refinement, and the ease of transforming to spherical harmonics when needed. Future applications of the method will combine both satellite constellation (Swarm) and airborne magnetic measurements to obtain models with locally enhanced resolution.

Presenting Author: Kotsiaros S.

Abstract Title: Estimating Swarm Magnetic Field Gradients for an Enhanced Determination of the Earth's Lithospheric Field.

Abstract Topic: Plans for exploitation projects

For the first time, part of the magnetic field gradient tensor is estimated in space by the Swarm mission. Yet a short-coming of Swarm appears to be the inability to provide estimates of the radial gradient of the magnetic field, which contains the most valuable information on the field signatures of the Earth's internal sources. However, analytical and numerical analysis of the spectral properties of the gradient tensor shows that specific combinations of the east-west and north-south gradients have almost identical signal content to the radial gradient. The east-west gradients can be approximated by observations from the lower pair of Swarm satellites, whereas the north-south gradients can be approximated by the first differences in the along-track direction. As a preliminary test, here we will present an analysis of along-track differences of CHAMP vector observations. These show considerably smaller standard deviations compared to conventional vector observations at almost all latitudes. Gradient data are less contaminated by large scale fields produced in the magnetosphere and ionosphere and specific gradient combinations can lead to an improved determination of both the lithospheric field and the high degree secular variation.

Presenting Author: Kovacs P.

Abstract Title: Monitoring of Intermittent Magnetic Fluctuations along the Orbit of the SWARM Spacecraft

Abstract Topic: Presentation of user projects and their initial results

The space and terrestrial magnetic observations exhibit signatures for the occurrence of deterministic nonlinear physical events in the solar-terrestrial system. Within the framework of a project devoted to the scientific exploitation of SWARM data, our goal is to find the nonlinear signatures in the ionosphere and investigate them in connection with local physical processes, such as electric currents, wave activities, anomalous ionization, density inhomogeneity, auroral particle acceleration. The project is entitled ‘The study of MHD waves, turbulence and the plasmasphere based on SWARM observations’.

In our preliminary study, a statistical analysis is carried out on the VFM time records of SWARM mission in order to discriminate between Gaussian and non-Gaussian magnetic fluctuation in the ionosphere. We apply probability density function (PDF) analysis of incremental magnetic field time-series of the individual SWARM records, and of spatial field differences measured between the simultaneous records of SWARM A and B spacecraft. Non-Gaussian behaviour of the spatial and temporal difference time-series can reveal multiscale intermittent magnetic fluctuation in the studied plasma region. The level of intermittent dynamics is measured by the fourth statistical moments of the increment time-series, i.e. by their flatness. Our aim is to investigate the variation of the flatness parameter in terms of the orbit of the SWARM spacecraft. Special intermittent events are further studied by power-spectral density function and high-order multifractal analyses. It is also intended to look for similar nonlinear features of the spaceborne VFM records and the nonlinear fluctuations of the geomagnetic field measured along the MM100 magnetometer array. MM100 consists of magnetometer stations located approx. along the 100 magnetic meridian and between the geomagnetic latitudes of 42 and 66 degrees. Each station provides high-resolution (at least 1 Hz), temporally synchronized geomagnetic vector field records.

Presenting Author: Laundal K.

Abstract Title: What is the Appropriate Coordinate System for Magnetometer Data when Analysing Ionospheric Currents?

Abstract Topic: Plans for exploitation projects

In this presentation we discuss which coordinate representation is most appropriate when analysing magnetometer data in terms of ionospheric currents, in particular the westward electrojet. The AL and the recently introduced SML index are frequently used as monitors of the westward electrojet. Both indices are based on ground magnetometers at auroral latitudes. From these magnetometers, the largest perturbation in the southward direction is selected as the AL/SML index at 1 minute cadence. The southward component is defined as antiparallel to the orientation of the horizontal part of the Earths' main field, B_H. The implicit assumption when using these indices as a monitor of the westward electrojet is that the electrojet flows perpendicular to B_H. However, B_H is in general not perpendicular to the westward direction in corrected geomagnetic (CGM) systems such as apex and the Altitude Adjusted Corrected Geomagnetic (AACGM) coordinate systems. We derive a new SML index, based on apex coordinates. We find that the new index has less variation with longitude and universal time (UT), compared to the traditionally defined SML. We argue that when analysing ionospheric currents using magnetometers, it is appropriate to convert the components to a corrected geomagnetic system. This is most important when considering longitudinal or UT variations, or when data from a limited geographical region is used. CGM coordinate conversion is also applicable on satellite vector measurements.

Presenting Author: Lesur V.

Abstract Title: Separating Internal and External Contributions to the Magnetic Field Using Harmonic Splines

Abstract Topic: Presentation of user projects and their initial results

One of the key quantities required to improve our magnetic field models is the time correlation function for the Gauss coefficients. To characterise these functions for each coefficient, the major difficulty is the separation of internal and external field contributions. We propose here an approach based on harmonic spline functions and using exclusively magnetic observatory data. The inversion process is set in the Bayesian framework. We extend to magnetic fields of external origins the harmonic spline introduced by Shure et al. (1982). As a result, all observatory data can always be fitted to their expected level of accuracy by both the external and internal harmonic splines. Then the separation between external and internal fields relies exclusively on the prior we give on these field behaviours. The technique has been tested on synthetic data sets and then applied on real data. The results show that the estimated Gauss coefficients have a large variance and that their estimated values depend on the number of observatory data used. With the present observatory distribution the maximum spherical harmonic degree resolved is not larger than 8. The technique is in principle applicable to satellite data.

Presenting Author: Macmillan S.

Abstract Title: Impact of early Swarm data on global magnetic field models

Abstract Topic: First science results

We investigate the impact of early Swarm data on global magnetic field models. Since November 2013, Swarm has been providing satellite vector magnetic data, the first since the end of the CHAMP mission over three years ago. We describe two models of the Earth's magnetic field, one of which incorporates Swarm data. Both models include data from the CHAMP and Ørsted satellites and from observatories. All data are similarly selected on the basis of local time, solar zenith angle, upstream solar wind conditions and magnetic activity. The different data are weighted according to their type, location and estimation of content of signal not being modelled. The time-varying large-scale magnetospheric field is co-estimated with the internal field.

We also provide an update on efforts to collate and check ground-based observatory measurements in support of the Swarm mission. These are particularly important for bridging the gap between CHAMP and Swarm as they provide the only accurate vector observations of the magnetic field during that time.

Presenting Author: Nose M.

Abstract Title: Swarm and Van Allen Probes Conjunction Observations of EMIC Waves and their Effects on O+ density Enhancement in Inner Magnetosphere

Abstract Topic: Presentation of user projects and their initial results

Previous studies employing the DE-1/RIMS instrument reported enhancements of O+ ion density in a limited range of L-value in the inner magnetosphere (i.e., L=3-6), which is called “the oxygen torus” [e.g., Chappell, 1982; Horwitz et al., 1984, 1986; Roberts et al., 1987; Comfort et al., 1988]. Recent study by Nose et al. [2011] used the magnetic field data and the plasma wave data obtained by the CRRES satellite in the inner magnetosphere, and identified enhancements of O+ density at L=4.5-6.5. It is of a great interest to examine how the oxygen torus is formed in the inner magnetosphere. One of possible scenarios may be as follows: Energetic ion injection in the inner magnetosphere leads to excitation of the electromagnetic ion cyclotron (EMIC) waves. The EMIC wave can be absorbed by thermal electrons through the Landau resonance interaction and heat the thermal electrons. The resultant heat is conducted down to the underlying ionosphere and raises the temperatures of ionospheric ions and electrons. This results in increases of the scale height of ionospheric plasma. Since the scale height of O+ ions is normally much smaller than H+ ions, even a small rise in scale height affects density changes at the topside ionosphere more strongly for O+ ions than for H+ ions. This causes a large number of O+ ions to diffuse into the high altitude and form the oxygen torus in the limited L-shell where the EMIC is excited.

In this study we report the 1 January 2014 event, in which Swarm and Van Allen Probes made conjunction observations supporting the above scenario. After sub storm onsets at 1840 UT and 1854 UT, Van Allen Probes-A, an equatorial orbiting satellite with an apogee of ~5.8 Re geocentric altitude, observed intermittent enhancements of EMIC wave activity in the helium band for 1920-1935 UT. In this time interval Probe-A moved from 61.5 deg to 62.5 deg in invariant latitude (ILAT) around local noon (MLT=12.0 hr). Swarm-A and -C, polar orbiting satellites at ~500 km altitude, traversed the same ILAT interval at MLT=11.5 hr. within 1 min around 1925 UT and observed magnetic fluctuations, which imply that EMIC waves were excited in a limited range of ILAT. Expecting that the EMIC waves induced diffusion of ionospheric O+ ions into the inner magnetosphere, we examined number density of H+ and O+ ions measured by Van Allen Probes-A. It was found that O+ number density was enhanced around ILAT range where the EMIC waves were observed. Van Allen Probes-B, which had the almost the same orbital segment of Probe-A with 1 hour delay, also observed O+ number density enhancement around the same ILAT range, while no EMIC waves were observed. This indicates that diffusion of ionospheric O+ ions lasts more than 1 hour after the heating of the ionosphere. We will present the observations from the fleet of 4 satellites (Swarm-A, -C, Van Allen Probes-A, and -B) and discuss how plausible the above scenario for the oxygen torus formation is.

Presenting Author: Park J.

Abstract Title: The Swarm Level 2 Category-2 products: Field-Aligned Current, Ionospheric Bubble Index, and Total Electron Content

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems)

This presentation will provide results of first validation activities on three Swarm Level-2 Category-2 (CAT-2) data products: Field-Aligned Current (FAC), Ionospheric Bubble Index (IBI), and Total Electron Content (TEC). The FAC product gives field-aligned and radial current density estimated from single-satellite and/or dual-satellite observations of geomagnetic field vectors. The resultant data shall be used for studying high-latitude field-aligned currents as well as low-latitude wind dynamo currents. The IBI product consists of flags showing whether a magnetic field data point is disturbed by plasma irregularities or other artificial noise sources. This product can be exploited in geomagnetic field modelling as well as in studying ionospheric scintillation climatology, or to identify plasma irregularity events. The TEC product is composed of slant electron content estimates integrated along the line of sight from Swarm up to the GPS satellites. This product monitoring the electron content of the upper ionosphere and plasmasphere can be a useful input to global data assimilation. All the three CAT-2 products are derived from Level-1b data: vector magnetic field, electron density, and GPS readings, as well as from auxiliary data. From our first scientific validations, we conclude that the CAT-2 processors for FAC, IBI, and TEC provide reasonable results based on current Swarm observations. Quantitatively, the CAT-2 will become even more reliable at the rate the quality of the Level-1b data improves.

Presenting Author: Patrick M.

Abstract Title: Evolution of Auroral Energy Dissipation Structures Determined Using Poynting Flux Measured by Swarm

Abstract Topic: First science results, Presentation of user projects and their initial results

The three Swarm satellites each carry a vector and scalar magnetometer as well as an Electric Field Instrument (EFI) that can be used to measure ion drift velocities. During the first months of the mission the satellites were in circular, polar orbits at an altitude of 490 kilometres, following each other in a pearls-on-a-string arrangement, separated by about one minute in time. This relatively close spatial formation allows comparisons to be done between electric field measurements on each satellite, revealing temporal changes of spatial structures. In this project we combine EFI data with vector magnetic field measurements to determine ionospheric Poynting Flux using each Swarm satellite. Cross correlation functions are calculated between measurements on each satellite and used to characterize the temporal and spatial scales of observed features. We find that on minute timescales, large-scale (~50-km-wide) regions of downward Poynting flux persist, but smaller-scale features evolve significantly.

Presenting Author: Philippov S.

Abstract Title: Attempt to Use the Stratospheric Balloon Gradient Magnetic Data for Verification of the SWARM Data

Abstract Topic: Presentation of user projects and their initial results

The idea of this work is to compare the lithospheric geomagnetic field and its gradient for three magnetic data sets: (a) the SWARM mission data (altitude of 460-530 km); (b) the stratospheric balloon data (altitude of 25-30 km); (c) the data of Map of lithospheric fields of Russia (ground level, Ed. Makarova). Balloon data were obtained on 22 March 2013 during the balloon flight along the profile length about 900 km (start point is 47°E.LON., 52° N.LAT.; finish point is 61°E.LON., 54° N.LAT.) at the altitudes of 25-30 km. The balloon carried three magnetometers, which measured the scalar of the geomagnetic field at three heights - 0 m, 3000 m and 6000 m below the balloon basket. Thus, we have six geomagnetic field measurements (three scalar measurements and three vertical gradient measurements) for one coordinate point (latitude, longitude). It is assumed to use the geomagnetic field secular variation data for reducing the first two data sets (a, b) to the same epoch. It is supposed to choose (on the available SWARM data interval) the quietest geomagnetic day with minimal value of the daily variation. It is supposed to build the spherical-harmonic geomagnetic field model for this day by SWARM data. Using this model we are going to determine the main field at the altitudes of the balloon flight. We accept the synthesized geomagnetic field based on our model (SWARM data) as the main geomagnetic field. Then, we delete this field from our balloon data. Hence, we can get one of the versions of the lithospheric field along the balloon flight profile. Another version of lithospheric field along the balloon flight profile has been already created according to the model IGRF2010. Taking the data from the map of Makarova as "basic" data and comparing them with other versions of mentioned above lithospheric fields (including its gradient), we can get some conclusions (as we hope) about the quality of the SWARM mission data.

Presenting Author: Pinheiro K.

Abstract Title: On the Applicability of Backus' Mantle Filter Theory

Abstract Topic: Plans for exploitation projects

The idea of this work is to compare the lithospheric geomagnetic field and its gradient for three magnetic data sets: (a) the SWARM mission data (altitude of 460-530 km); (b) the stratospheric balloon data (altitude of 25-30 km); (c) the data of Map of lithospheric fields of Russia (ground level, Ed. Makarova). Balloon data were obtained on 22 March 2013 during the balloon flight along the profile length about 900 km (start point is 47°E.LON., 52° N.LAT.; finish point is 61°E.LON., 54° N.LAT.) at the altitudes of 25-30 km. The balloon carried three magnetometers, which measured the scalar of the geomagnetic field at three heights - 0 m, 3000 m and 6000 m below the balloon basket. Thus, we have six geomagnetic field measurements (three scalar measurements and three vertical gradient measurements) for one coordinate point (latitude, longitude). It is assumed to use the geomagnetic field secular variation data for reducing the first two data sets (a, b) to the same epoch. It is supposed to choose (on the available SWARM data interval) the quietest geomagnetic day with minimal value of the daily variation. It is supposed to build the spherical-harmonic geomagnetic field model for this day by SWARM data. Using this model we are going to determine the main field at the altitudes of the balloon flight. We accept the synthesized geomagnetic field based on our model (SWARM data) as the main geomagnetic field. Then, we delete this field from our balloon data. Hence, we can get one of the versions of the lithospheric field along the balloon flight profile. Another version of lithospheric field along the balloon flight profile has been already created according to the model IGRF2010. Taking the data from the map of Makarova as "basic" data and comparing them with other versions of mentioned above lithospheric fields (including its gradient), we can get some conclusions (as we hope) about the quality of the SWARM mission data.

Presenting Author: Plattner A.

Abstract Title: Altitude Vector Slepian Functions and Satellite Crustal Magnetic Field Data: First Examples

Abstract Topic: Presentation of user projects and their initial results, Plans for exploitation projects

For Swarm satellite data, as for any other satellite data set, the sensitivity to noise in the downward-continuation process is influenced by the maximum spherical-harmonic degree with which we fit the data. The necessity to choose a maximum spherical-harmonic degree forces local geophysical processes (crustal magnetic field features) into a global mathematical description (spherical harmonics). This duality is particularly problematic if the crustal magnetic field is varying strongly locally. Under a spherical-harmonic degree cut-off, a weakly magnetized area adjacent to a strongly magnetized area will contain high-degree spherical-harmonic energy, a spectral leakage exacerbated by the downward continuation. Thus, even with excellent data and global coverage, a global spherical-harmonic analysis will generate artefacts in weakly magnetized regions adjacent to strong features. One way to avoid this problem is to use local functions for fitting only local data.

Any such local basis of functions needs to be of finite spherical-harmonic degree to quell the noise amplification in the downward-continuation process. Since no band limited spherical-harmonic expansion can be perfectly spatially localized, we construct local functions whose spatial energy outside of the target area is minimized. Care should be taken to avoid focusing the spectral energy in the high spherical-harmonic degrees since those experience most noise amplification.

To satisfy all these constraints we construct localized functions via optimization. In addition to localization, our altitude vector Slepian functions concentrate as large as possible a fraction of their spectral energy within a bandwidth that is minimally sensitive to noise under downward continuation. We show the benefits of using these functions for geomagnetic vectorial satellite-data crustal magnetic field inversions in an example involving data collected by Mars Global Surveyor between 1997 and 2006. We demonstrate their aptness for calculating local crustal magnetic fields if only local high-quality data are available and their ability to avoid artefacts from field intensity variations.

By implication, altitude vector Slepian functions will be ideally suited for localized analysis of the high-quality data collected by Swarm over the locally strongly varying crustal field of Earth.

Presenting Author: Puethe C.

Abstract Title: New constraints on Earth's Radial Conductivity Structure

Abstract Topic: Plans for exploitation projects

We present a pre-Swarm model of the radial (1-D) conductivity structure of Earth's mantle. This model was derived from 12 years (September 2000 to December 2012) of magnetic measurements of the three satellites Orsted, CHAMP and SAC-C and the global network of geomagnetic observatories. To remove contributions of core, lithospheric and ionospheric fields, we made use of CM5, the latest version of the Comprehensive Model series. We subsequently fitted the residuals with external and induced coefficients.

From coefficient time series, we estimated C-responses, which we then inverted for the global 1-D conductivity profile with the Newton method. An iterative approach was used to correct the estimated responses for 3-D effects arising from lateral heterogeneities in the top 10 km. The Hessian matrix of the misfit function, which we derive analytically, is used to estimate confidence limits for the conductivity of each layer. The resulting conductivity-depth profile is compared to 1-D conductivity models of Earth's mantle recovered in previous studies.

Presenting Author: Puethe C.

Abstract Title: A Pre-Swarm 3-D Mantle Conductivity Model, Derived With the Q-matrix Approach

Abstract Topic: Plans for exploitation projects

We present an update of our 3-D frequency domain inversion scheme to recover global 3-D mantle conductivity from satellite magnetic data. The inversion scheme is based on a new set of global electromagnetic transfer functions, which form an array that we denote as Q-matrix (which is a 3-D generalization of 1-D scalar Q-responses). The Q-matrix relates external (inducing) and internal (induced) coefficients of the spherical harmonic expansion of the time-varying magnetic field of magnetospheric origin. It is estimated from time series of these coefficients, which will in the Swarm mission be provided by the Comprehensive Inversion. The modified inversion algorithm has been successfully tested with realistic test data from the development phase of the Swarm mission.

As global induction studies require several years of data, we applied the elaborated concept to existing data in order to obtain a pre-Swarm mantle conductivity model. We used 12 years (September 2000 to December 2012) of magnetic measurements of the three satellites Orsted, CHAMP and SAC-C and the global network of geomagnetic observatories. To remove contributions of core, lithospheric and ionospheric fields, we made use of CM5, the latest version of the Comprehensive Model series. We subsequently fitted the residuals with external and induced coefficients up to degree 3 and order 1. The coefficient time series were used to estimate the Q-matrix and as input for a time domain approach (Velimsky et al.), which is presented separately. First 3-D inversion results are discussed.

Presenting Author: Purucker M.

Abstract Title: Do We Need to Make Suborbital Measurements of the Magnetic Field?

Abstract Topic: First science results

A local technique for mapping magnetic crustal thickness is developed and utilized to examine the question of the need for suborbital observations of the geomagnetic field, as for example from a high altitude aircraft or UAV. It can be shown (Blakely, 1995; Hildenbrand et al., 1996) that there exists a significant gap in the wavelength sensitivity between low-altitude airborne and satellite magnetic surveys but it has been difficult to quantify the importance of the 'missing' intermediate (200-400 km) wavelengths. Some of the missing spectral information will be available from Swarm as the gradient configuration descends to lower altitude, and some can be recovered from specialized, long-distance and low-altitude surveys that tie together the existing patchwork of low altitude magnetic surveys (Milligan et al., 2010). Because of the absence of systematic observations from 20 km altitude we utilize the ellipsoidal EMM2010 model (Maus, 2010) which contains both near surface and satellite data to degree 720, and can be evaluated quickly on the dense (0.1 degree) grids that we need. The technique is an adaptation of a technique developed by Fox Maule et al. (2005) and uses as a starting model the Crust 1.0 seismic thickness model (Laske et al., 2013). We compare our model output from this new adaptation of the technique to other magnetic, seismic and thermal approaches (cf. Bouligand et al., 2009) in the western U.S. and elsewhere. The intent is to examine in detail the intermediate spectral signature, and its importance, in areas where we think it is adequate (Australia and perhaps parts of the western U.S.) and in areas where we think it is inadequate (Greenland and the Aleutians). We demonstrate with Swarm data from 10 April (KP<0+, all local times) the gradient sensitivity possible with

Swarm, and speculate on the degree to which Swarm will fill the gap in the intermediate wavelength range.

Presenting Author: Quesnel Y.

Abstract Title: The Sources of the Bangui and West Africa Magnetic Field Anomalies Constrained by Satellite Data and Rock Magnetism

Abstract Topic: Presentation of user projects and their initial results, Plans for exploitation projects

Large magnetic field anomalies are observed over the Central African Republic (the Bangui Magnetic Anomaly) and over the Western part of Africa (the West Africa Anomaly). They correspond to Precambrian crusts enriched in iron by different (and debated) processes. Using ground and satellite gravity and magnetic field data, new crustal models will be built for some of these areas. Rock magnetic property measurements on samples will constrain these models.

Resulting from a preliminary study over the BMA, a 4.3 A/m-magnetized 38 km-thick iron-rich crust corresponds to one of the best models that fit all these data. Only BIFs and some migmatitic rocks of this area can lead to such magnetization intensities. However, BIFs are commonly found near surface, and show weak metamorphism. Therefore we will also investigate the vertical variation of BIF's magnetization using pressure experiments and magnetic field gradient SWARM satellite data inversion.

Presenting Author: Ridley V.

Abstract Title: Validation of Swarm Satellite Magnetic Data using Observatory Measurements

Abstract Topic: First science results, Presentation of the outcome of the Cal/Val activities

The scientific use of Swarm magnetic data and Swarm-derived products is greatly enhanced through their combination with geomagnetic observatory data and indices. The strength of observatory data is their long-term accuracy, with great care being taken to ensure temperature control/correction, platform stability and magnetic cleanliness at each site. Recent work to improve the coverage and timeliness of observatory data has been encouraged and now over 60 INTERMAGNET observatories and several other high-quality observatories are providing close-to-definitive data within 3 months of measurement.

An effort is being made to use these measurements to ground-truth Swarm data as part of the mission's Calibration/Validation phase. These observatory data are gathered and homogenised on a regular basis by BGS and those collected during overhead passes of the Swarm satellites are identified. For each pass, we remove an estimate of the main field from both the data collected at altitude and that collected on the ground. Both sets of data are then normalised relative to the data variance during all passes since launch. The absolute differences of the two sets of normalised data can be used as a metric of satellite data quality relative to observatory data quality. When we analyse the results obtained for each Swarm satellite alongside those found when a complementary analysis is carried out on CHAMP, the findings are similar.

Presenting Author: Rother M.

Abstract Title: A Magnetic Core Field Model Derived from Swarm Satellite Data

Abstract Topic: First science results

Nearly six months of Swarm satellite data have been recently released. The data set covers nearly all local time, but is not yet fully calibrated. Further, usual geomagnetic indices and other data usually used for the data selection process are not yet available. We nonetheless attempted to produce a model following the usual GRIMM approach where the data are selected during night-times and for magnetically relatively quiet periods. The knowledge on the Gauss coefficient correlation, acquired during the CHAMP epoch, is used as a prior to stabilise the field derivation process. The magnetic field is assumed to vary linearly in time. Preliminary results will be shown. They will be compared with the most recent version of the CHAOS-4 model and used to look at first estimates on Euler angle corrections.

Presenting Author: Sabaka T.

Abstract Title: CM5: A pre-Swarm magnetic field model based upon the comprehensive modelling approach

Abstract Topic: Presentation of the outcome of the Cal/Val activities

We have developed a model based upon the very successful Comprehensive Modelling (CM) approach using recent CHAMP, Oersted, SAC-C and observatory hourly-means data from September 2000 to the end of 2013. This CM, called CM5, was derived from the algorithm that will provide a consistent line of Level-2 data products for the Swarm mission. This algorithm uses a special statistical treatment that allows certain parameter subsets to be determined from the best suited data subsets. Indeed, this allows for a co-estimation of parameters describing the magnetic field of the ionospheric Sq current system and the lithospheric with no contaminating leakage into the latter. The lithospheric field compares well with MF7 and CHAOS-4 at least to spherical harmonic degree 90. In addition, we have estimated the magnetic field generated by the oceanic M2 tidal constituent, which compares well with simulations using the known M2 tidal flow. This model will be useful for magnetic induction studies as well as providing a reference model for Swarm-based models coming soon.

Presenting Author: Schack P.

Abstract Title: First Investigations on Swarm Level 1a Accelerometer and Star Tracker Performances

Abstract Topic: Presentation of the outcome of the Cal/Val activities

SWARM, ESA's magnetic field mission launched in November 2013, is incorporating three identical satellites in different orbits to gain enhanced knowledge about the Earth's magnetic field. During four years mission time, Swarm-Alpha and Swarm-Charlie will decay from 460 km to 300 km orbit height in side-by-side orbits. Swarm-Bravo differs by the orbit height (530 km in the beginning of the mission) and the inclination, leading to diverging orbital planes.

In order to obtain accurate magnetic field and electron flux measurements, a good performance of the integrated sensors on-board is mandatory. This includes, among others, the GPS sensor and star trackers as part of the attitude and orbit control system and the accelerometer. The data of these sensors needs to be analysed in order to validate their performance before they are used to derive higher level products. This contribution presents first results regarding the performance analysis of the accelerometers and the three star trackers mounted in the middle of each satellite's boom. Thereby, the instruments characteristics will be assessed in the time domain, the spatial domain and the frequency domain.

Presenting Author: Stolle C.

Abstract Title: Energy Deposition in the Ionosphere Derived from LEO Satellite Observations

Abstract Topic: First science results, Release of Swarm Level 1 data products, Presentation of user projects and their initial results, Plans for exploitation projects

Ten years of successful operation of the multi-instrument CHAMP satellite mission at a unique orbit altitude of about 400 km revealed many interesting features of the coupling between the thermosphere and ionosphere. Different processes contribute to the deposition of solar and magnetospheric energy into the thermosphere. One important venue is heating through thermal electrons transferring energy by collisions with ions and neutrals. In the ionospheric F region thermal electrons are heated primarily through photoelectrons by local or non-local processes. At high latitudes soft precipitation and electromagnetic heating play a major role. The energy deposition can be quantified by a family of chemo-physical equations (Schunk and Nagy, 2009) that depend on plasma and neutral densities and temperatures. Sizeable electron cooling rates in the F region have been published from EISCAT radar observations in the ionospheric cusp. Based on CHAMP observation of electron density and temperature we estimate the energy deposit in the F-region through cooling of the thermal electron gas caused by elastic and inelastic processes. Our analyses support former findings, that ion-electron Coulomb collisions play a primary role in the F-region. This process is largely dominated by the electron density. We find that a significant deposition is present during day at mid-latitudes. At low latitudes the energy flux remains important until midnight. Observed heating rates depend on the satellite altitudes, but they are globally available from the CHAMP data. Missing observations in the CHAMP dataset, e.g., ion temperature, are derived from empirical models as IRI or MSIS. We investigate the global distribution of the electron cooling rate, we quantify the contributions of the different processes (equations) to the total energy transfer, e.g., depending on height and latitude, and we compare our results with radar observations. Our focus is to apply Swarm observations also including ion temperature. We are interested in evaluating possible improvements when using the new Swarm observations instead empirical model results.

Presenting Author: Taylor P.

Abstract Title: Preliminary Validation of Swarm Anomalies with Magsat and CHAMP-Simulated Swarm Anomalies using CHAMP as a Proxy

Abstract Topic: Presentation of user projects and their initial results

We wanted to evaluate how future Swarm data could be used to interpret satellite altitude crustal magnetic anomalies by simulating these data with ten years of CHAMP measurements. We chose the Kursk Magnetic Anomaly (KMA) for a test site and collected ten years of the CHAMP mission magnetic data over this region. Total magnetic field anomaly and east horizontal gradient maps were made. From potential theory, peaks in the horizontal gradients indicate the edges of bodies with anomalous magnetization. We mapped a distinct u-shaped gradient anomaly map over the KMA and gradient profiles indicated the dimensions of this body. Our results mapped an area of approximately 190,000 km2. Since with the newer Swarm data we will be able to make higher signal to noise magnetic gradient anomaly maps and therefore be able to map, with greater detail, regions of anomalously magnetized crust.

Presenting Author: Triebnig G.

Abstract Title: New Ideas for Swarm Data Selection and Visualization - Introduction of ESA Technology Study VirES

Abstract Topic: Presentation of user projects and their initial results, Plans for exploitation projects

The ESA technology study "Virtual Workspace for EO Scientists - VirES" aims at specifying a user exploitation platform primarily for Swarm but also other Earth Explorers missions. The project puts focus on new ideas and advanced Web based mechanisms for data selection from archives, visualization of products as integrated geospatial displays, as well as on-demand processing and results delivery.

The user consultation and requirement collection phase of VirES will run until end of September 2014. Together with a parallel system design this shall form the starting points for various prototyping and technology demonstrations activities with results expected in early 2015. The project follows an Open data and Open Source Software development logic.

This paper contains initial information about:

- Means for data set discovery in the Swarm mission archive;
- Novel visualization possibilities for Level 1B products (daily calibrated and reformatted single satellite data interesting for scientific community) and Level 2 product (high value constellation products such as magnetic field models etc.);
- Data sub-setting e.g. based on different solar-terrestrial conditions;
- Virtualization approaches related to data access and processing invocation.

ESA and the study team are hoping for science community feedback and therefore organize a survey based on structured interviews of attendees directly at the conference. The paper will also explain how interested parties can collaborate with the project during specification and prototype implementation stages.

Presenting Author: Vanhamaki H.

Abstract Title: Positive Definite 2D Maps of Ionospheric Conductances Derived from Swarm Electric and Magnetic Measurements

Abstract Topic: Presentation of user projects and their initial results, Plans for exploitation projects

Amm et al. have developed a new analysis technique for Swarm electric and magnetic field measurements, which allows us to derive 2-dimensional maps of ionospheric conductances, currents, and convection in the area between and around the trajectories of the two parallel flying Swarm spacecraft. The analysis method is based on fitting the measured electric and magnetic fields in terms of Spherical Elementary Current Systems (SECS).

In the previously presented "standard" version of the analysis technique the electric field and current system are solved independently of each other, so in some cases the inevitable accumulation of measurement and analysis errors may cause the resulting conductances to become negative in parts of the output map. For those cases we have developed a "positive definite" version of the analysis

algorithm, where the procedure for fitting the electric field data is modified to take into account the previously calculated current system and to guarantee positive Hall and Pedersen conductances.

In practice we fix the horizontal current distribution obtained from magnetic field analysis, and represent the Hall and Pedersen conductances with positive definite functions, such as exp(x). 2D map of the positivity parameter x is then obtained by fitting the Swarm electric field measurement, with possible additional constraints on spatial smoothness. This results in a non-linear minimization problem that can be solved with standard techniques.

In this presentation we outline the calculation procedure and show some test cases, where the synthetic Swarm measurements based on realistic ionospheric phenomena are analysed. We show that the "positive definite" analysis method does indeed give positive conductances in all cases, and in areas where the "standard" method works well the results are in very good agreement.

An iterative solver is used in the non-linear minimization procedure, making the positive definite method at least order of magnitude slower than the standard method. Therefore we recommend that the positive definite method should be used only in those cases where the standard analysis results in negative conductances.

Presenting Author: Velímský J.

Abstract Title: Determination of 3-D Mantle Conductivity from the CM5 Dataset

Abstract Topic: Presentation of user projects and their initial results

A time-domain approach to the 3-D global inversion of observatory and satellite data has been developed in the preparation for the Swarm mission (Velímský 2013). This approach relies on the separation of individual contributions to the total geomagnetic field by means of comprehensive modelling (Sabaka et al. 2013). While Swarm data are being accumulated, we apply this method to the dataset of ground observatory, CHAMP, Ørsted, and SAC-C vector and scalar data used in the derivation of the latest generation of the Comprehensive Model CM5. 12-years long residual time series of spherical harmonic coefficients representing the magnetospheric sources, and their induced counterparts, are interpreted in terms of regularized 3-D conductivity models.

Presenting Author: Velímský J.

Abstract Title: Magnetic Signatures of Barotropic and Baroclinic Ocean Flows in Swarm Data

Abstract Topic: Presentation of user projects and their initial results

One of the scientific tasks of the Swarm mission is to detect and ideally to interpret the magnetic signatures caused by motional induction of conductive seawater in the Earth's oceans.

Our projects aims at the following objectives:

- to construct a covariance-matrix estimate of the magnetic field induced by barotropic and baroclinic ocean circulation model;
- to develop and apply the time-domain EM induction modelling program to predict the magnetic signatures of ocean flows in measurements provided by low-altitude satellites;
- to develop a new method of reducing an oscillatory feature of modelled magnetic field induced by ocean flow along coastal lines;
- to assess the effect of the toroidal magnetic field induced inside oceans on the Swarm magnetic data;
- to assess the effect of single-layer approximation for modelling of the poloidal magnetic field at Swarm altitude;
- to develop a new algorithm for extracting magnetic signals from Swarm data;
- to apply the ensemble Kalman filter for assimilating Swarm magnetic data into ocean flow models.

Methodology and initial results will be presented.

Presenting Author: Vervelidou F.

Abstract Title: A Global Estimate of the Earth's Magnetic Crustal Thickness

Abstract Topic: Plans for exploitation projects

The Earth's lithosphere is considered to be magnetic only down to the Curie isotherm. Therefore the Curie isotherm can be, in principle, estimated by analysis of magnetic data. Here, we propose such an analysis in the spectral domain by means of a newly introduced regional spatial power spectrum. This spectrum is based on the Revised Spherical Cap Harmonic Analysis (R-SCHA) formalism (Thébault et al., 2006). We briefly discuss its properties and its relationship with the Spherical Harmonic spatial power spectrum. This relationship allows us to adapt any theoretical expression of the lithospheric field power spectrum expressed in Spherical Harmonic degrees to the regional formulation. Therefore in this study we make a combine use of this regional spectrum and a statistical expression we recently proposed for the power spectrum of the magnetic field of the Earth's lithosphere. More precisely, we conduct a series of regional spectral analyses for the entire Earth. For each region, we estimate the R-SCHA surface power spectrum of the NGDC-720 Spherical Harmonic model (Maus, 2010). We then fit each of these observational spectra to the statistical expression. By doing so, we estimate the large wavelengths of the magnetic crustal thickness on a global scale that are not accessible directly from the magnetic measurements due to the masking core field. We then discuss these results and compare them to the results we obtained by conducting a similar spectral analysis, but this time in the cartesian coordinates, by means of a published statistical expression (Maus et al., 1997). We also compare our results to crustal thickness global maps derived by means of additional geophysical data (Purucker et al., 2002; Laske et al., 2013). We conclude that a global scale estimation of the magnetic crustal thickness based merely on magnetic data is of interest but that new magnetic data, both satellite and aeromagnetic, are expected to ameliorate the performance of our approach. Our study shows that robust estimations of the magnetic crustal thickness require an accurate knowledge of the magnetic power spectrum of the Earth's lithosphere over a large band of wavelengths. Such knowledge is currently inhibited by the spectral gap between satellite and aeromagnetic data. In this respect the SWARM mission is expected to ameliorate our knowledge about the crustal thickness by bridging the spectral gap between these two data types.

Presenting Author: Wardinski I.

Abstract Title: Forecasts of Geomagnetic Secular Variation

Abstract Topic: Presentation of user projects and their initial results

We attempt to forecast the geomagnetic secular variation based on stochastic models, non-parametric regression and singular spectrum analysis of the observed past field changes. Although this modelling approach is meant to be phenomenological, it may provide some insight into the mechanisms underlying typical time scales of geomagnetic field changes. We follow two strategies to forecast secular variation:

Firstly, by applying time series models, and secondly, by using time-dependent kinematic models of the advected secular variation. These forecasts can span decades, to longer periods. This depends on the length of the past observations used as input, with different input models leading to different details in the forecasts. These forecasts become more uncertain over longer forecasting periods. One appealing reason is the disregard of magnetic diffusion in the kinematic modelling. But also the interactions of unobservable small scale core field with core flow at all scale unsettle the kinematic forecasting scheme.

A further (obvious) reason is that geomagnetic secular variation cannot be mimicked by linear time series models as the dynamo action itself is highly non-linear. Whether the dynamo action can be represented by a simple low-dimensional system requires further analysis.

Presenting Author: Xiong C.

Abstract Title: Latitudinal and Apex Height Variations of Equatorial Plasma Irregularities as Observed by LEO Satellites and Jicamarca Radar

Abstract Topic: First science results

The equatorial plasma irregularities (EPIs) stand for a localized region of plasma density depletion in the night-time low latitude F-region, which have been observed in the past few years by different techniques (e.g. ground-based radar, digisonde, GPS, optical instruments, in situ satellite and rocket instrumentation). In this report three EPI events from the in-situ electron density measurements of Swarm satellites, in conjunction with Incoherent Scatter Radar (ISR) observations at Jicamarca, show that the EPIs with greater apex heights can extend to higher latitudes. In-situ EPI observations from CHAMP, GRACE and ROCSAT-1 have also been investigated. The latitudinal distribution of EPI occurrence rates exhibits two peaks symmetrical about the dip equator at CHAMP and GRACE altitude, while exhibits one peak above the dip-equator at ROCSAT-1 altitude. We further checked the inter-hemispheric asymmetry of EPI detected by CHAMP and GRACE, with respect to the magnetic declination angle. All these results support the notion that the EPIs form regions of depleted plasma along geomagnetic fluxtubes.

Presenting Author: Yin F.

Abstract Title: Precise Science Orbits for the Swarm Satellite Constellation

Abstract Topic: Mission status after the commissioning phase (satellites, instruments, operations, science data systems)

a) Introduction

CHAMP (CHAllenging Minisatellite Payload), a German small satellite mission to study the Earth's gravity field, magnetic field and upper atmosphere, ended in space on 19 September 2010. Thanks to the good quality of the satellite and several altitude manoeuvres, the satellite provides continuous and reliable observation data including House-Keeping data in different levels for almost 11 years. Among them, the high-resolution vector magnetic field data observed by FGM (FluxGate vector Magnetometer) with 50Hz sample rate are one of the most important data products. 50Hz sample rate allows us to investigate all signals from 0Hz to 25Hz.

b) Method and Results

Two kinds of signals with specific frequency are founded regularly in 50Hz vector magnetic field data by spectrum analysis, one is ~2.1Hz harmonic signal and the other is ~8Hz single sinusoid signal. The features of these two kinds of signals are characterized and analysed respectively, which helps us to trace the signals to neither natural source nor artificial source from ground, but the satellite itself.

c) Discussion & Conclusion

2.1Hz harmonic signals mainly depend on the incident of sunlight, which are probably related with FGM nearby instrument ASC (Advanced Stellar Compass). 8Hz single sinusoid signals vary with the temperature inside of the satellite and depend on the distributions of the FGM data values, which indicate the source of them locates in the FGM. Similar signals are not founded in magnetic field data of SWARM satellites temporarily.

Presenting Author: Zakharenkova I.

Abstract Title: Multi-Instrumental Study of Ionospheric Response to Geomagnetic Storms: Perspectives for SWARM Mission

Abstract Topic: First science results

Multi-instrumental studies by using data from Low Earth Orbit (LEO) satellite missions have already proved to be very efficient in investigations of global redistribution of ionospheric plasma and thermosphere mass density during such phenomena as geomagnetic storms. LEO satellites with high inclination orbit can cover areas such as oceans, deserts with absence of ground-based detectors. LEO satellite can have various instruments for research of the ionosphere response to the space weather events like GPS receiver for precise orbit determination, total electron content estimation and radio occultation, altimeter, planar Lungmuir probe, topside sounder, special detectors for particle fluxes, magnetometer etc. One of the main and rather important limitations is that a number of existing LEO satellites are mainly solo-satellite missions, their data along one orbit track is not sufficient to monitor space weather rapid changes on a global scale and should be accumulated on long-term basis (weeks, months) or incorporated into background model.

The recent ESA mission SWARM presents a constellation of three LEO satellites placed into three different polar orbits. This rather unique constellation has extremely valuable payload for study of the ionosphere-magnetosphere coupling, in particular magnetometers, accelerometer, electric field instrument, GPS receivers. Another advantage of the mission is the orbit altitude of 460 km for tandem and 530 km for SWARM-C – it is the region just above the ionospheric F layer peak and measurements from this topside region is of high importance for the ionosphere research.

It is believed that only multi-instrumental and multi-satellite data analysis of the ionosphere behaviour during space weather events of varying intensity can represent the complex modification and dynamics of the upper atmosphere in different altitudinal, spatial and temporal scales. In this paper, we show several examples of joint analysis of LEO satellite data, in particular CHAMP, DMSP, JASON, for global ionospheric response to the geomagnetic storms. Also we present the preliminary analysis results of the first scientific data available for public. We are looking forward for using of very promising SWARM mission data to ionospheric studies.

Presenting Author: Zhang X.

Abstract Title: The Comparison and Cross-validation in Plasma Parameters among Different Electromagnetic Satellites

Abstract Topic: Presentation of user projects and their initial results

The reliability of observing data from electromagnetic satellite is the basis of scientific research, including ionosphere physics and earthquake research, and also it is the key factor to examine and evaluate the payload designing and data pre-processing technology. After two or three years, SWARM and CSES will operate simultaneously in ionosphere, which provides a unique opportunity for us to do the cross-validation between them in electromagnetic field and plasma parameter observation. Here we introduce some initial results in China on this project.

The methods were used to validate the plasma data by comparison of satellite data with IRI model, other satellite data and different plasma parameters. The results show that in local night-time around 22:30 the global distribution of Ne by the DEMETER satellite exhibited similar behaviour as that by IRI-2007 model, but Ne is overestimated above 100% by the IRI in equatorial and beyond geomagnetic latitudes of 50°, while underestimated by -70% at 20-40° in both hemispheres. In local daytime around 10:30, Ne values are mostly overestimated by the IRI model especially in the equatorial area where double crests were exhibited clearly at ±10° in the IRI-NeQuick model, but only one crest left around 0-10° N shown by DEMETER. The data from other satellites such as CHAMP, Hinotori, and DE-2, operated at different altitudes imply that there might exist a kind of altitude effects i.e. the double crest due to the fountain effect over the equatorial area would gradually evolve into a single crest above 600 km from the bottom of the ionosphere, or to say the EIA would have not formed at LT 10:30 at the height of the DEMETER satellite. The comparison of Ne from ISL and Ni from IAP both installed on DEMETER showed good linear correlation between them at LT 1030, but big difference occurred at LT 2230 with much larger Ne detected to one or two orders of amplitude than Ni. It provided another validation tool for estimating the reliability of Ne observation during solar minimum when heavy contamination of photoelectrons might exist.

Future plan: 1) the validation by ground-based Radar observation; 2) the comparison with occultation observation; 3) cross-validation among different satellites by Chapman function.