Temporal Variations of the Geomagnetic Field

Nils Olsen
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The high-precision geomagnetic missions Ørsted, CHAMP and SAC-C during the present “International Decade of Geopotential research” provide an unprecedented possibility to derive models of the Earth’s magnetic field and its time changes. The talk will discuss various approaches to model temporal changes of the core field from magnetic satellite observations, and results obtained using data from the first part of the “Decade of Geopotentital Research”.

A magnetic view of the African crust and lithosphere

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Much of Africa’s surface geology is ‘cover rocks’, relics of deposition, extrusion and erosion since Precambrian times. The Precambrian basement below is obscured by them and much of what we know about the structures and lithologies of the basement has to be inferred indirectly by geophysical mapping. The Precambrian not only contains much of Africa’s solid mineral potential, but its structure has largely determined the distribution of the sedimentary basins and their potential for petroleum. Better understanding of African Precambrian geology is therefore of enormous practical importance in the continent’s economic future. Magnetic anomalies arise mostly from the Precambrian basement, providing a ‘window’ through the cover with which to map its lithology and structure.
Aeromagnetic reconnaissance of Africa is far from complete, but its compilation (African Magnetic Mapping Project, 1989-92) offers new information on the crustal mosaic of Africa and its relation to previously neighbouring continents in Gondwana. While several large countries have yet to get started with systematic surveying, others have already moved on to surveys of ‘second generation’ resolution, resolving detail at the level of tens of metres, sustaining new applications such as in groundwater exploration. The overview provided by satellite-altitude magnetic (lithospheric) anomalies provides its own new insights – and raises some interesting questions about potential impact events that may necessitate new directions in African geodynamics.

**Invited talks 2**  
**Thursday, Sep 4, 2003, 9:00-10:00**  
**Chair: Hermann Lühr**

### Global Electrical Conductivity and Magnetic Satellite Induction Studies

**Steven Constable, Catherine Constable**  
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Semiconduction in mantle minerals results in a thermally activated electrical conductivity that can, in principle, be used to map temperature in the deep Earth. The largest conductivity variations in Earth, however, are from pressure-driven phase changes which create more conductive minerals and a radial electrical structure. The 670 km seismic discontinuity, thought to be the olivine/pyroxene -> perovskite/wustite transition, is almost certainly an important electrical discontinuity, and recent laboratory studies suggest that high pressure olivine phases in the transition zone are also more conductive than uppermost mantle minerals. The effects of temperature could also be confounded by variations in chemistry- recent discussion has centered mainly on the role of hydrogen as a conductive defect in olivine. While hydrogen conduction is subject to a variety of criticisms, it highlights the fact that mantle electrical conductivity is governed by defects existing at concentrations measured in parts per million, and so an understanding of volatile chemistry is important to interpretations of mantle conductivity.

Traditionally, deep Earth conductivity is probed by surface records of electromagnetic fields. For crustal prospecting the magnetotelluric method is favored, in which a frequency domain transfer function between electric and magnetic recordings provides an impedance of the subsurface. However, electric fields are subject to galvanic distortion, and it is difficult to maintain the integrity of cables and electrodes over decades of time, and so very long period studies use observatory magnetic records. There are two problems with this approach: the global observatory distribution is biased, and assumptions generally have to be made about the morphology of the magnetic source field before one can carry out the internal-external field separation.

Magnetic satellites have potential to address both these issues, with global coverage and sufficient redundancy to model the morphology of both the source field and the induced field. On the other hand, they present formidable challenges in separating spatial and temporal signals. We have been moderately successful in removing static fields associated with the main field and crustal magnetization, as well as field variations associated with quiet time ionospheric currents, using the Comprehensive Model of Sabaka et al., to create records in which the majority of the field can be modeled with a ring current source.

The internal-external separation necessary for induction studies can be carried out using the vector spatial morphology of the fields during each orbit. We can apply time series analysis to the internal and external records for the duration of the mission to obtain a globally averaged 1D (radial) Earth structure, or we can examine the spatial distribution of the internal/external field ratio to probe lateral variations in conductivity. Initial analysis of Magsat data produced promising results from both these methods, with the global ocean basins visible in the spatial pattern of the induced fields and also evident as a surface conductor in the radial conductivity model. Lower mantle conductivity may be higher than that estimated from observatory records, possibly because of the difference between assuming an axially symmetric ring current geometry (observatory studies) and fitting a ring current geometry (satellite analysis). Better, longer, lower altitude records from CHAMP and improvements in the Comprehensive Model will allow us to confirm and extend these results.

### Ionospheric plasma effects for geomagnetic LEO missions at mid- and low-latitudes

**Matthias Förster**  
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Some of the main plasma characteristics are reviewed that a LEO satellite with high orbital inclination encounters during its travel across the terrestrial ionosphere of mid- and low-latitudes. It is the region of
highest plasma density in the near-Earth environment. Its properties are predominantly ruled by the geomagnetic field.

It will be shown how different ionospheric layers - first of all the E- and F-layer - contribute in different ways to the electrodynamic and thermodynamic behaviour of the highly interacting, complex system comprising the ionosphere, thermosphere, and plasmasphere. The physical description of its phenomena and data interpretation have nowadays to rely to a substantial part on numerical methods and models.

New observational methods and space missions have essentially contributed to the recent progress in this field. The CHAMP mission takes part in this progress just as much as the IMAGE, TIMED, and other satellite projects as well as ground-based observation programs.

The paper summarises recent developments in ionospheric studies as, e.g., the plasma transport at mid- and low-latitudes, the regular Sq-dynamo and the contribution of the F-region dynamo, the interhemispheric coupling by current systems and plasma flows, pulsations, the equatorial electrojet and the plasma fontaine effect, the Appleton anomaly, the near-equatorial plasma bubbles, and further open questions. One particular aspect is the dependence of magnetic field measurements itself on the surrounding plasma conditions due to the diamagnetic effect.

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**Session M 1: Lithospheric Fields & Geological Interpretation**

**Tuesday, Sep 2, 2003, 11:30-13:00**

**Chair:** Ingo Wardinski

**Introduction: Two years of CHAMP magnetic field mission**

H. Lühr
GeoForschungsZentrum, Potsdam

*abstract under construction*

**Crustal field modelling from CHAMP scalar and vector magnetic data**

S. Maus, M. Rother, H. Lühr, G. Balasis, and K. Hemant
GeoForschungsZentrum, Potsdam

Comparison of CHAMP Flux Gate Magnetometer (FGM) repeat tracks reveals that crustal features with wavelengths down to 400 km (corresponding to spherical harmonic degree 100) are clearly visible. However, due to the presence of instrument errors, time varying external fields and ocean current signals, extending crustal magnetic field models to such high degrees without excessive damping is challenging. Here, we present our processing scheme which removes the major non-crustal contributions to the magnetic field. In the initial step we identify and classify periods containing high frequency signals, using a wavelet technique (see abstract of Balasis et al.). From the cleaned data set of night time scalar and vector measurements we then subtract the POMME main and external field model (see abstract of Maus et al.). Remaining external fields are removed by fitting and subtracting a 3-parameter model from individual 120-degree track segments, separately for the polar and mid latitudes. In this step, an attitude correction for the vector data is co-estimated. By a harmonic analysis, we then identify and subtract the ocean tidal contribution to the field, which is in itself an interesting product. From the final data set of cleaned crustal field residuals, the custal field model is estimated by a standard least squares technique.

**The lithospheric field from the latest comprehensive model**

T.J. Sabaka and N. Olsen

One of the major magnetic field sources considered in our "comprehensive" approach to modelling the terrestrial magnetic system is the lithosphere. The most recent of these models, CM4, uses a combination of data from the POGO, Magsat, Oersted and CHAMP magnetic mapping mission to resolve the lithospheric field. Comparison with CHAMP-derived lithospheric field models reveals several interesting differences which may be related to external field leakage and vector magnetometer misorientation. These differences will be discussed and remedies proposed.
Interpretation of CHAMP crustal field anomaly maps using a Geographical Information System (GIS) technique

Kumar Hemant, Stefan Maus and Volker Haak
GeoForschungsZentrum, Potsdam

Crustal field models from CHAMP magnetic measurements are increasingly stable and reliable (see abstract of Maus et al.). In particular, they now allow for quantitative geological studies of crustal structure and composition. Here, we use a forward modeling technique to infer deep crustal structure of continental regions overlain by young cover. For this, a Geographical Information System (GIS) based technique has been developed to model the various geological units of the continental crust. Starting from geologic and tectonic maps of the world and considering the known rock types of each region, an average susceptibility value is assigned to every geological unit. Next, the vertically integrated susceptibility (VIS) is generated by taking into account the seismic crustal thickness, as given by models 3SMAC and CRUST2.1. From this initial VIS model, the a priori vertical field anomaly map is computed at a satellite altitude of 400 km and compared with the corresponding CHAMP vertical field anomaly map. Modeling results are discussed for selected provinces of the world. We demonstrate that significant geological inferences can be made from the agreement and the discrepancies between our a priori prediction and the observed anomaly map.

Magnetic Petrology Database for Interpretation Lithospheric Magnetic Anomalies

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In spite of the numerous efforts to understand the nature of satellite magnetic anomalies, the origin of most of them is still unclear. The interpretation of lithospheric magnetic anomalies is inherently non-unique and complimentary magnetic petrology information is essential for developing global magnetic models. A Global Magnetic Petrology Database (MPDB) is now being compiled at NASA/Goddard Space Flight Center and consists of many thousands of records. The purpose of this database is to provide the geomagnetic community with a comprehensive and user-friendly method of accessing magnetic petrology data via Internet for a more realistic interpretation of satellite (as well as aeromagnetic and ground) magnetic anomalies. MPDB is focused on lower crustal and upper mantle rocks and includes data on mantle xenoliths, serpentinitized ultramafic rocks, granulites, iron quartzites and rocks from Archean-Proterozoic metamorphic sequences from all around the world. The definition of crustal magnetic anomalies is improving due to the mini-constellation of three satellites - Ørsted, Champ, and SAC-C. Recent lithospheric field models (CM3e, MF1, MF2) reveal magnetic anomalies with better resolution, for example in the areas of Iceland, Polar Urals Mountains, and Anabar Shield where we have an excellent magnetic petrology records. A prototype of database under development can be found at: http://core2.gsfc.nasa.gov/research/terr_mag/php/MPDB/frames.html

M 1 Posters (in alphabetical order)

Polar lithospheric field from multiple satellite observations

Benoit Langlais(1), MICHAEL PURUCKER(2), Susanne Vennerstrøm(3)
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(3) Danish Space Research Institute, Copenhagen, Denmark.

Mapping the magnetic field of lithospheric origin is a key to better understanding the properties of the oceanic and/or continental lithosphere. Models are usually based on local, airborne surveys, or on satellite datasets. The first kind of data doesn't allow large scale anomalies to be well modeled. The second one usually relied on the scalar measurements of the POGO series, or on the short time mission MAGSAT. The launches of Ørsted (Feb. 1999), CHAMP (Jul. 2000) and SAC-C (Nov. 2000) gave a new opportunity for studying the magnetic field of the Earth from the satellite perspective. This mini-constellation, which can be considered as a small satellite observatory network, provides for the first time multiple, simultaneous field measurements at satellite altitude. Of particular interest is the data density above the North and South pole areas of the Earth. In this study, we use the equivalent dipole source method to model the lithospheric field over polar (+/- 60 deg) areas. We use a multiple step approach. First, data are selected globally, with respect to the local time and external magnetic perturbations. Spherical Harmonic (SH) models are built,
using either short-time data subsets, or pluri-annual measurements. The core contributions are then removed from the measurements. The computed residuals are carefully selected, in order to remove as much external perturbations as possible. Because only the total intensity enters the SH model, it is possible to use the average of the component perpendicular to the main field direction to determine the quiet intervals. The sorted residuals are then used to infer the susceptibility of field-aligned dipoles located in the lithosphere. The modeled dipoles are finally used to predict the magnetic field of lithospheric origin at a constant altitude. A comparison with other models is shown. A discussion with respect to the season (winter or summer) is presented, as well as a comparison between the North and South pole areas.

Magnetic crustal thicknesses in Greenland from CHAMP and Ørsted data

C. Fox Maule, M. Purucker, N. Olsen and K. Mosegaard

Magnetic crustal thicknesses in Greenland and the surrounding area are determined through inversion of satellite magnetic data. The data used as basis for the inversion is the IDEMM model, which is based on CHAMP and Ørsted data, and the Comprehensive model, which is based on a coestimation scheme. The magnetic crustal thicknesses are determined by iteratively improving an initial model, which is obtained by combining data of Moho depths with a thermal model for the area. The equivalent source magnetic dipole method is used to calculate the induced magnetic field of the crust from the initial model of the magnetic crustal thickness. By inversion the difference between the calculated induced field and the observed induced field is used to determine a correction to the magnetic crustal thickness. By adjusting the initial model with this correction a new and better estimate of the magnetic crustal thickness is made. This process is repeated until the difference between the calculated induced field and the observed induced field is below the uncertainty of the data. From the obtained Curie depths we hope to estimate the geothermal heat flux in the area.

CHAMP magnetic anomalies of the Antarctic lithosphere

Hyung Rae Kim (1), Ralph R. B. von Frese (1), Luis R. Gaya-Pique (2), Patrick T. Taylor (3), Jeong Woo Kim (4)


Magnetizations of the Antarctic lithosphere are constrained by CHAMP and Ørsted magnetic and gravity observations and near-surface surveys. At satellite altitudes, the spatially and temporally static lithospheric magnetic anomalies are very weak compared to the significant dynamic effects of the polar external fields. Moreover, the more regional lithospheric signals are strongly masked by core field components and hence difficult to isolate. These non-lithospheric factors combine to greatly reduce the lithospheric magnetic signal-to-noise ratio in the polar regions relative to the rest of the Earth. We can, however, use spectral correlation theory to separate static lithospheric and core field components from the dynamic external field effects. To help isolate regional lithospheric from core field components, the correlations between free-air and terrain gravity effects can be exploited using the pseudo magnetic effects of the crustal thickness variations. Employing these procedures, we processed the CHAMP magnetic and gravity observations for an improved magnetic anomaly map of the Antarctic lithosphere. These CHAMP magnetic anomalies at 400 km altitude now show new details that were difficult to identify in earlier Magsat observations, which were obtained in austral summer and fall when the interfering effects of the external field were strongest.

Balloon Geomagnetic Survey at Stratospheric Altitudes

K. Nazarova, Yu. Tsvetkov, J. Heirtzler, T. Sabaka

In July 1996 the total intensity of the geomagnetic field was measured at an altitude of approximately 30 km by a balloon flight from Kamchatka on the east to the Caspian Sea covering the Sea of Okhotsk, the Central Siberian Platform, the West Siberian Plains and Urals Mountains. This 6000 km traverse was made at a latitude of about 55° N in 6 days. The measurements were made with a scalar proton-precession magnetometer with an accuracy about 0.2 nT. The CM3e model was used to remove the main and external fields from the observed data and then a linear slope with respect to longitudes was removed. Distinctive magnetic anomalies were observed over the mountains of Kamchatka, the Dzbugdzhur Range west of the Sea of Okhotsk, and over the Urals Mountains. There are generally positive anomalies over the Siberian Platform and negative over the Siberian Plains. A distinct positive magnetic anomaly of about 300 nT was
identified over the Urals Mountains. There is agreement over Ural Mountains and Kamchatka between balloon magnetics and recent lithospheric magnetic models CM3e and MF2 based on Champ data. The flight was over the area covered by a Russian aeromagnetic map compiled in 1993 and in general shows similar anomalies in similar places when adjusted for the altitude differences. Another study of the gradients of the geomagnetic field by stratospheric balloons with the three proton magnetometers separated along a 4 km vertical line at equal distances, showed more detailed magnetic anomalies over Aldan Shield and Enisey Folding Belt. New balloon gradient magnetic measurements are planned in summer 2003.

Manuscript of Tibetan plume structure and seismicity of High Asia in regional geophysical fields

Valentin Pogrebnoy, Tamara Sabitova

This paper presents the results of complex analysis of High Asia geophysical fields in regional scale which show peculiarities of tectonic structure and ongoing in the region geodynamic processes. Based on juxtaposition of maps of following regional fields like geoidal undulations, anomalous magnetic and gravity fields, heat flow, shear wave attenuation, the Raleigh wave group velocities distributions for periods $T=10^{-7}$-0.7s, Pn-wave velocity distribution in upper mantle of High Asia we guess that all of those are caused by anomaly body which might consist of deconsolidated and hot material and hereafter named by authors as Tibetan plume. There has been suggested its structure. According to quantitative and qualitative interpretation of geophysical fields, the Tibetan plume represents a steep ellipsoidal body (horizontal projection) where the longer axis size is approximately 2500 km and the shorter axis is 1000 km with narrow branches on the west side. Its depth extension is traced, as a through column, down to >300km from day surface. Judging by geographical location, a great extent both in spread and depth as well as geophysical fields which display it, the Tibetan plume is independent formation but not consequence of continental plate collision. From comparison of seismicity and geophysical fields, it was made inference about correct correlation between seismic events and geophysical field structure. High gradients zones of geophysical fields were found to be indicators of possible strong event zones. This criterion can be used for solution of a problem of revelation of seismogenous zones in seismic zoning of certain High Asia regions. It is noted that the location of such large deconsolidated body in High Asia which formed, most likely, due to ejection of a large amount of hot and deconsolidated substance onto upper layers of the High Asia tectonosphere, has an influence on dynamic processes in this region. Dynamic processes in High Asia region are guided with combination both of collision between Indostan and Eurasia lithospheric plates and ongoing development of Tibetan Plume. This investigation was carried out with support from International Science and Technology Center (ISTC), Project KR-214.

Merging satellite and aeromagnetic data over Europe, the North Atlantic and Arctic

M. Purucker (NASA/GSFC) and K. Whaler (U. Edinburgh)

Utilizing the 5 km aeromagnetic grids assembled from the European magnetic compilation project (Wonik et al., 2001) and the Arctic-North Atlantic compilation (Roest et al., 1996), and a global total field map at 400 km incorporating CHAMP data (Sabaka et al., 2003), we merge these data by jointly inverting them. There are more than a million elements in each of the aeromagnetic compilations. We use a harmonic spline basis (Shure et al., 1983) and utilize a sparse matrix/conjugate gradient approach to make the problem tractable. We find the model with minimum power in the radial field at the Earth's surface, for a given fit to the data. Based on a similar formalism (Parker et al., 1987), we also model continuously varying magnetization, minimizing its RMS amplitude within the crust. We expect that the resulting total field anomaly map, with long wavelength control and preserving the resolution of the original grids, and the associated magnetization map, will be useful for interpretation.
Effect of varying crustal thickness on CHAMP geopotential data


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To determine the effect of crustal thickness variation on satellite-altitude geopotential anomalies we compared two regions of Europe with vastly different values, Central/Southern Finland and the Pannonian Basin. Crustal thickness exceeds 62 km in Finland and is < 26 km in the Pannonian Basin. Heat-flow maps indicate that the thinner and more active crust of the Pannonian Basin has a value nearly three times that of the Finnish Svecofennian Province. Ground based gravity mapping in Hungary shows that the free-air gravity anomalies across the Pannonian Basin are near 0 to +20 mGal with shorter wavelength anomalies from +40 to <-60 mGal and some 0 to <-20 mGal. Larger anomalies are detected in the mountainous areas. The minor value anomalies can indicate the isostatic equilibrium for Hungary (the central part of the Pannonian Basin). Gravity data over Finland are complicated by de-glaciation. CHAMP gravity data (400 km) indicates a west-east positive gradient of >4 mGal across Central/Southern Finland and an ovoid positive anomaly (~4 mGal) quasi-coincident with the magnetic anomaly traversing the Pannonian Basin. CHAMP magnetic data (425 km) reveal elongated semi-circular negative anomalies for both regions with South-Central Finland having larger amplitude (<-6 nT) than that over the Pannonian Basin, Hungary (<-5 nT). In both regions subducted oceanic lithosphere has been proposed as the anomalous body.

Reliability of CHAMP anomaly continuations

Ralph R.B. von Frese (1), Hyung Rae Kim (1), Patrick T. Taylor (2)

1) Dept. of Geological Sciences, The Ohio State University, (2) NASA/GSFC, Geodynamics Branch

CHAMP is recording state-of-the-art magnetic and gravity field observations at altitudes ranging over roughly 300-550 km. However, numerical simulations and comparisons with Ørsted magnetic anomalies at higher altitudes (> 650 km) and near-surface magnetic and gravity data from airborne, shipborne, and terrestrial surveys reveal that the satellite anomaly accuracies severely limit the process of anomaly continuation. Our results show that effective downward continuations of the CHAMP data are restricted to within approximately 100 km of the observation altitudes while upward continuations can be effective over a somewhat larger altitude range. This apparent unreliability of downward continuation requires that the satellite geopotential observations must be analyzed at satellite altitudes if the anomaly details are to be exploited most fully. Given the current anomaly error levels, we believe that the best approach for implementing satellite geopotential observations for subsurface studies is by joint inversion of satellite and near-surface anomalies. To demonstrate the power of this approach, we produce a crustal model for the Antarctic Maud Rise in the southwest Indian Ocean from joint inversions of near-surface and satellite magnetic and gravity observations. Our modeling suggests that the dominant satellite altitude magnetic anomalies are produced by crustal thickness variations and remanent magnetization of the normal polarity Cretaceous Quiet Zone.
Influence of non-potential fields on calibration of vector data

R. Holme
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In transforming vector data recorded by a vector magnetometer into an Earth-centred, Earth fixed frame, the Euler angles for the transformation from the frame of the magnetometer to that of the star camera are a crucial ingredient. Since Magsat, these have been solved for in orbit simultaneously with a main field model; essentially they are varied to minimise the non-potential field. However, it has become clear that non-potential field sources in the rotating Earth frame (for example, fields arising from the magnetotail) can covary with the determination of the angles, leading to misleading values. I consider how much of the variation in Euler angles could be due to such sources, consider the effect of such variation on field models, and present possible strategies for users to account for uncertainty in the Euler angle transformation.

Introducing POMME, the Potsdam Magnetic Model of the Earth

S. Maus, H. Lühr, G. Balasis, M. Rother, GeoForschungsZentrum Potsdam
M. Mandea (IPGP)

With three years of magnetic field measurements from CHAMP and four years from Ørsted, the main magnetic field and its secular change can be modelled with unprecedented accuracy. Our field model introduces several new features:
(1) External fields are parametrised in SM, GSM and GSE coordinate systems, accounting for the geometry of the ring current, the magnetosphere and the solar wind. (2) We use a combination of global vector data and global scalar data sets, instead of the usual approach of using vector data at low latitudes and scalar data at high latitudes. (3) The angles between CHAMP's star camera and its vector magnetometer are co-estimated in a joint inversion with the Ørsted data. (4) The model includes 2nd time derivatives of the magnetic field to account for the non-negligible secular acceleration in the surveyed period.
As inferred from the degree spectrum, the secular variation is reliable at least to degree 11 and the secular acceleration to degree 6. The overall accuracy of the model and its predictive capability are assessed by a comparison with observatory data.

Satellite data and wavelets frames. A New view of the Earth's magnetic field

Aude Chambodut, Mioara Mandea and Matthias Holschneider.

A new representation of the main field on the sphere was developed, by choosing an approach which always makes a direct relation between the spherical harmonics (SH) and wavelets (Holschneider, Chambodut, Mandea, 2003). Our work was mainly the theoretical description of the wavelets on the sphere in order to use them in field modelling. Our first results in modelling the Earth's magnetic field from observatory data using the wavelet basis underlined the applicability of the method. The comparison with the SH models showed how well the wavelets describe the magnetic field on a global scale. The regional features of the field are also observed in this global representation.
Here we present the first results obtained when magnetic satellite data are used. Once more, our attempt is to produce two representations, using SH and wavelets. The same data distribution is used. However, the SH are applied on a vector dataset (mainly X,Y,Z components, and F for high latitudes or when vector data are missing), and wavelets on a scalar one (computed from previously used X,Y,Z, and the same F as before). This gives us the new possibility to study the "Backus effect" in modelling the main field, and the superposition of the main and crustal field for wavelengths of about 3000 km.
Alternative parameterisation of the external magnetic field and its induced counterpart for 2001 and 2002 using Ørsted, CHAMP and observatory data

Lesur, V., Macmillan, S. and Thomson, A.

A better parameterisation of the field generated by the large-scale magnetospheric current systems (i.e. the magnetopause current, ring current and tail current) is needed to avoid further filtering of the data when modelling the crustal magnetic field. Using Ørsted and observatory data for year 2001, we investigate a new parameterisation where internal and external degree one Gauss coefficients are computed daily. These models are compared with ‘standard’ models where the external field is parameterised with a linear dependence of the hourly Dst index. For both types of model the fit to the data is similar despite the poorer resolution in time of the former models. Therefore, we introduce faster variations in time for the internal and external degree one Gauss coefficients. Preliminary results show an improvement in fit to the data. The same modelling approach is used to model the geomagnetic field for year 2002 using both vector and scalar CHAMP satellite data.

New insights into the secular variation between MAGSAT and CHAMP/ØRSTED

Ingo Wardinski and Richard Holme

In this study we developed models for the secular variation over this period. Our method is based on an approach proposed by Bloxham and Jackson (1992); a decomposition of the magnetic potential in spherical harmonics and expansion in time of its coefficients on a basis cubic B-Splines. The essential new feature of our method is the use of Main field models as constraints for the field at the endpoints, 1980 and 2000. These models were derived from high-quality satellite vector data. For the intervening period our most useful data are secular variation estimates derived from magnetic observatory measurements. External variation is significant, but simple parameterization of this in terms of an uniform external field proves inadequate, we investigating ways of mitigating the effects of external fields on our model, particularly those from the ring current.

Our resulting models are in good agreement with the models developed by Bloxham and Jackson for 1980 until 1990. Furthermore we have indication for small scale secular variation structure.

M 2 Posters (in alphabetical order)

Time structure of the 1991 magnetic jerk in the core-mantle-boundary zone by inverting global magnetic data supported by satellite measurements

Ludwig Ballani (1), Ingo Wardinski (2), Dietrich Stromeyer (3) and Hans Greiner-Mai (1)
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New global magnetic data (Gauss coefficients, monthly values, up to degree and order 10 from 1980 to 2000) partly based on high-quality satellite vector data (MAGSAT and CHAMP/ØRSTED) are processed with a recent non-harmonic downward continuation method. It solves the related inverse boundary value problem by approximating the solution (time function at the interesting radial level, e.g. at the core-mantle boundary) of an equivalent Volterra integral equation with a smoothing minimum-norm solution. An extended version of this inversion procedure enables the determination of the magnetic field in the top layer of the fluid outer core if in addition the fluid velocities are prescribed and the depth is limited to about 100km.

Assuming a weakly conducting mantle and the highly conducting fluid in the outer core we calculate field components which show the temporal structure of the jerk in 1991 at the core-mantle boundary and for different depths underneath prescribing alternative types of velocities.
Use of CHAMP magnetic data to improve the Antarctic geomagnetic reference model

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CHAMP total field measurements have been used to develop the new version of the Antarctic geomagnetic Reference Model (ARM). The model was conceived as a tool to evaluate the main field in Antarctica, facilitating the merging of different magnetic surveys carried out in the region from 1960 onwards. Spherical cap harmonic analysis was used to produce the model. Together with data coming from Pogo, Magsat, and Ørsted satellite missions, a suitable selection of CHAMP data based on different criteria was performed to minimise the effect of external fields. Since CHAMP satellite tracks cover the Geographical South Pole better than other satellite missions, this fact contributed to improve the model in the central region of the cap.

Secular variation of the geomagnetic field from satellite data

V.P. Golovkov, T.I. Zvereva and T.A. Chernova
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Secular variation was separated as a natural orthogonal component (NOC) in NOC’s expansion of the sets of coefficients of the spherical harmonical (SH) models of the geomagnetic field. SH models for specially selected very quite days (both in $k_p$ and $D_{st}$) during time interval from January 2000 to June 2003 have been derived (one day per month was taken). Each SH model of the field on satellite vector data of whole day was derived, including as well data from high latitude regions and of all local times. Only two sources of data have been used: Ørsted and CHAMP satellite vector second mean data. Then, for processing by NOC method, SH coefficients were organized into a rectangular matrix, in which the matrix column were sets of SH coefficients and rows corresponded to time change of some SH coefficients. Applying the NOC method has allowed us to obtain the secular variation space-time model as the first component in NOC-expansion. Advantages of used method are discussed.

The spectrum of the magnetic secular variation

Richard Holme (University of Liverpool) and Nils Olsen (DSRI, Copenhagen)

Power spectra have proved to be a powerful tool for examining the nature of the geomagnetic field. Application of depth-to-source techniques for the main field power spectrum place source depths near the core-mantle boundary and in the lithosphere, as we would expect on physical grounds. Similar techniques applied to the secular variation place the source depth in the mid-mantle, which cannot be justified physically. Here, we show that this result arises from an inappropriate definition of the power spectrum. Taking the ratio of the secular variation spectrum to that of the main field yields a curve well fit by a power law in spherical harmonic degree. Thus, we argue that with appropriate definition of the SV spectrum, the source depth of the SV is appropriately located near the CMB.

Problems and advantages in using ground-based and satellite magnetic field data

Wigor A. Webers
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As known from the potential field theory the knowledge of the field in all points of the space including the source region is necessary for a unique relation between the field and its source. In practice this “complete” field is not available. Necessarily, every form of upward and downward field continuations are inverse problems that do not have a unique solution. As a consequence simultaneous field models of the magnetic field that are independently determined on concentric reference surfaces contain important physical information to be used. The comparison of independently determined magnetic field models from these separate simultaneous data sets with mathematically upward and downward
continued field models gives details for the field constituents being a tool to separate internal and external contributions of the magnetic field. Improving upward and downward field continuation as much as possible is required by the high quality of the data being available at the Earth's surface and from satellites as e.g. Ørsted and CHAMP. The related altitudes of these satellites have to be taken into account for field continuation more carefully to derive field models and interpretations of high quality being adequate to the accuracy of the field data used. The calculations for the magnetic field models for the ground in comparison to that of Ørsted and CHAMP show how the mathematical background is used for geophysical interpretation.

Session M 3: Induced Fields, Ocean Currents & Poster Summaries M 1 - M 6
Tuesday, Sep 2, 2003, 16:00-17:30
Chair: George Balasis

Geomagnetic induction modelling based on CHAMP magnetic vector data

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The first results of modelling geomagnetic induction signals induced by equatorial ring currents in the magnetosphere recorded at satellite altitudes, are presented. The input of the model consists of the X-component of the magnetic induction vector measured by the CHAMP vector magnetometer along individual night-time satellite tracks. The magnetic induction signals measured along day-time tracks and above polar regions are not considered because they are disturbed by signals with sources different from ring currents. Thus, only mid-latitudes are considered. Only periods during magnetic storms with time scales of the order of days are analysed because the induced signal is most intense.

Forward modelling of magnetic induction is implemented in the time domain using the spectral-finite element method developed by Martinec et al. (2003) and recently modified for satellite data. The output is the Z-component of the magnetic induction vector at satellite altitudes. We test the sensitivity of the computed Z-component using an electrical conductivity model for the Earth's mantle. We then compare the output with CHAMP magnetic data and evaluate the acceptability of the electrical conductivity model adopted. We show that a spherically symmetric model of electrical conductivity is too restrictive to adjust to the Z-component of the CHAMP magnetic data for all night-time, mid-latitude satellite tracks over a magnetic storm.

For near-future considerations, this implies the necessity to introduce a more complex conductivity structure of the Earth's mantle when interpreting the CHAMP magnetic induction data.


Electromagnetic induction by Sq ionospheric currents in a heterogeneous Earth: Modeling using ground-based and satellite measurements

Jakub Velímský and Mark E. Everett
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The long-term topic of our research is determination of the constraints imposed by the satellite-born magnetometer data on the 3-D conductivity structure of the Earth's mantle and lithosphere. Recently we have created a database consisting of hourly means of the geomagnetic field components observed on quite days in years 2001 and 2002 on ground observatories and Oersted satellite measurements covering the same time intervals. In the first step we use the Oersted model of the main geomagnetic field to subtract the static component from the measurements. The external and internal parts of the field are separated using the expansion into partial sums of spherical harmonics. In the next step, the responses of 3-D conductivity models of Earth's mantle and lithosphere to the external field variations are numerically modeled. Coastline effect and effect of lithospheric conductivity on the surface and satellite data is studied.
Identification, classification and separation of F-region currents, orbit errors and instrument noise in CHAMP FGM data using a wavelet technique

G. Balasis, S. Maus, H. Lühr, and M. Rother
GeoForschungsZentrum, Potsdam

Wavelet spectral analysis permits quantitative monitoring of the signal evolution by decomposing a time-series into a linear superposition of predefined mathematical waveforms (‘wavelets’), each with finite duration and narrow frequency content. Thus, the frequency range of the analyzing wavelets corresponds to the spectral content of time-series components. We present a wavelet analysis of 1Hz CHAMP Flux Gate Magnetometer (FGM) data. It enables us to identify and separate not only artificial noise (e.g. orbit errors and instrument problems) but also high frequency natural signals of external fields (e.g. F-region currents and pulsations). The result of the analysis is three-fold: (1) Identification of instrument and pre-processing problems for correction and flagging. (2) A clean data set to be used in main and crustal field modeling. (3) A classified data set for future studies of the identified natural signals, like pulsations and F-Region currents.

Modelling the coast effect of geomagnetic storms at ground and satellite altitude

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We investigate the coast effect of geomagnetic storms at satellite altitude by means of a joint analysis of ground and satellite data using the following approach: (1) Time series of the horizontal components at worldwide distributed observatories are Fourier transformed; (2) At each frequency, the space structure of the external storm variation is determined (as a spherical harmonic expansion) from the horizontal components and from a given model of electrical conductivity; (3) The magnetic field induced by the external field in a 3-D Earth with non-uniform oceans is calculated. For this aim the frequency domain integral equation solution is used; (4) Finally, time series of magnetic field of the storm are synthesized at ground and satellite altitude using a Fourier transform and are compared with the observations. We previously successfully applied this scheme to explain the anomalous behaviour of geomagnetic storms at coastal observatories. Here we investigate its application to satellite data.

3-D modelling of the magnetic field due to oceanic tides

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We present the results of three-dimensional (3-D) simulations of the magnetic field variations caused by global oceanic tides. The tidal models are taken from Egbert et al. (1994). The 3-D conductivity model of the Earth incorporates laterally inhomogeneous oceans and continents that are underlaid either by radially symmetric (1-D) mantle or by 3-D mantle. To simulate the magnetic fields integral equation solution has been exploited. The results are analysed at the surface of the Earth, as well as at CHAMP and OERSTED altitudes. We compare our results for the $M_2$ tide with the model results of Tyler et al. (2003).
Comparison of different methods and models to detect field-aligned currents from magnetic observations by polar orbiting satellites

Peter Stauning, Freddy Christiansen, Jurgen Watermann, and Ole Rasmussen
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The magnetic perturbations observed from low-altitude, polar-orbiting satellites have been used to detect field-aligned current (FAC) structures in the polar regions. Large-scale models of the spatial and temporal FAC distribution at different seasonal and solar wind conditions have been constructed in various ways spanning from simple averaging of data to more sophisticated mathematical models. These models, however, involve elements of smoothing of fine-scale intensity variations as well as averaging over upward and downward FAC. Accordingly they tend to underestimate the actual detailed currents deduced orbit by orbit by the simpler gradient-related techniques. The presentation will provide a comparison between the predictions offered by different large-scale models and will, furthermore, give estimates of the differences between the predictions by the large-scale models and the scale-dependent FAC results from analysis of individual orbits.

Small-scale, field-aligned currents at the top-side ionosphere

Freddy Christiansen (1) and Torsten Neubert (2)
(1) Danish Meteorological Institute, (2) Danish Space Research Institute

High-precision vector magnetic field observations from the Ørsted satellite are used to investigate small-scale, field-aligned currents on spatial scales down to 600 m. Placed in a low-Earth, polar orbit, the slowly drifting orbit plane has covered all local times since launch in 1999 with more than 25000 polar passes. Small-scale currents are primarily found in the cusp with densities of 10-100 µAm-2, reaching more than 1000 µAm-2 during disturbed conditions. These values are 1-2 orders of magnitude larger than large-scale region 1 and 2 currents. Current densities are 2-4 times larger when the ionosphere is illuminated than when in darkness. While the location of currents follows the changes in cusp location with changing IMF, the intensity of the currents seems to depend on the level of solar wind turbulence. The data suggest that small-scale currents may be associated with significant local heating of the ionosphere and thermosphere.

Characterisation of high-latitude ionospheric current systems during very quiet times

Patricia Ritter(1), Hermann Lühr(1), Ari Viljanen(2), Ilkka Sillanpää(2) and Stefan Maus(1)
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CHAMP passes the geographic poles at a distance of 2.7° in latitude, thus providing a large number of magnetic readings of this dynamic region. The data of these numerous overflights were used for a detailed statistical study on the level of activity. A large number of tracks with very low RMS of the residuals between the scalar field measurements and a high degree field model were singled out over both the northern and southern polar regions independently. Low RMS values indicate best model fit due to very low activity. The occurrence of very quiet periods is strongly controlled by the solar zenith angle indicating the importance of the ionospheric conductivity. We present the correlation of the RMS values with the activity indices Kp, Dst, PC and IMAGE_Ae. Furthermore we investigate the horizontal ionospheric and field aligned current estimates for these very quiet periods. This study provides an insight into the external processes which lead to very quiet conditions. On average we observe low amplitudes of IMF By and Bz for hours before and after the quiet orbits. The Bz values generally show a pronounced shift to positive amplitudes just before the key time of the selected orbits. For main and lithospheric modelling endeavours this polar current activity statistics can be used as an improved selection criterion for quiet time datasets.
Impact of geomagnetic activity on thermospheric density

Eigil Friis-Christensen, Nils Olsen, Hermann Lühr

The joint analysis of the magnetometer and accelerometer data of CHAMP provides a unique possibility to study the influence of magnetic field variations on thermospheric density. The cusp region, located on the dayside at polar latitudes has shown to be of particular importance. We derive air-drag and air density variations from the “along-track” acceleration measured by the CHAMP accelerometer and compare those with simultaneous magnetic field measurements and existing models of thermospheric density.

The low-altitude cusp seen from various perspectives:
Multi-instrument observations during the February 2002 SIRCUS campaign

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The first SIRCUS (Satellite and Incoherent Scatter Radar Cusp Study) covered the time period February 16-22, 2002. It involved primarily the CHAMP and Ørsted PLEO satellites and the EISCAT (Tromsø and Svalbård) and Sondrestrom Incoherent Scatter Radars. Data from these sources were supplemented by ground-based magnetometer and DMSP–F13 and –F14 satellite observations and measurements in the solar wind. February 21 is particularly suited for a multi-instrument case study since all instruments involved were in operation and collected data. We attempt to identify the low-altitude cusp based on signatures derived from the different data sources, and discuss the consistency of the results. We further investigate the implications of the different observations and their consistency resp. inconsistency for a comprehensive description of the low-altitude cusp.

M 4 Posters (in alphabetical order)

Modelling of high-latitude geomagnetic field disturbances at satellite altitudes for various IMF conditions

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We present a new model of high-latitude geomagnetic field disturbances generated by the varying 3-D system of field-aligned and ionospheric currents at satellite altitudes. This model is based on the high-precision magnetic field measurements made onboard of the Ørsted and CHAMP satellites in 1999-2002. The model is parameterized by the interplanetary magnetic field (IMF) strength and direction, as well as by the Earth’s dipole tilt angle. Specific attention is paid to determining a set of geomagnetic variations during quiet conditions for different seasons; that is, when IMF nears zero. The latter allows us to better understand how the high-precision magnetic field surveys over high latitudes can be utilized for the main geomagnetic field modeling. We compare our ‘disturbance’ models for various IMF conditions and seasons with the actual satellite measurements to estimate how well our statistical patterns mimic observations along the orbits.

Modelling the Earth magnetic field of magnetospheric origin from CHAMP data

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A first attempt to parameterise the external magnetic field from CHAMP scalar data shows that there are still problems when modelling the magnetic effect of external currents. Usually the correction in main field modelling is done by the D_ST-index. Difficulties occur close to the poles and while doing a local time dependent modelling. In a second step CHAMP vector data are used to describe the effect of...
magnetoospheric currents. From time to time CHAMP is flying in resonance with the Earth rotation. It is very helpful to look at the differences between such 'repeat tracks'. Contributions of the lithosphere and model errors are eliminated. Before the inversion a correction around ±20° of the poles is done. Ampere's law integral is used for minimising non-scalar potentials. The integral is calculated over one full orbit and used for the pole correction. For the calculation the North- and Down-component are chosen, because the East-component is most influenced by field aligned currents. All calculations are done in geomagnetic coordinates and in a local time frame.

**Detection of intense fine-scale field-aligned current structures in the cusp region from the Ørsted satellite and from ground**

Peter Stauning, Freddy Christiansen, Jurgen Watermann, and Ole Rasmussen
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The magnetic perturbations observed from the Ørsted satellite in the low-altitude Cusp region indicate structures of very intense but thin sheets or narrow filaments of field-aligned currents up to several hundreds of μA/m² embedded in FAC structures of up to a few μA/m². The precision magnetic measurements made at high temporal resolution of 25 and occasionally 100 samples/sec corresponding to spatial resolutions down to 75 m has enabled us to detect fine-scale structures that often comprise mixed up- and downward currents within regions where the FAC at less detailed scales would be considered uniformly up- or downward oriented. The ionospheric electric fields and currents induced by the FAC can locally be much stronger than their averages. Among the consequences of the strong intensities and large variabilities in the FAC distribution on a detailed scale are patchy ionospheric backscatter resulting from E-region two-stream instabilities, highly variable ion drift velocities, and atmospheric upwelling resulting from strong Joule heating. These effects are experimentally verified characteristics of the ionospheric Cusp region. Ørsted magnetic data have provided detailed mapping of the characteristics and the distribution of fine-scale FAC intensities versus invariant latitude and local time as well as their dependence on solar wind plasma and magnetic field conditions. In the presentation these data are compared to observations obtained from ground-based instrumentations.

**One-dimensional upward continuation of the ground magnetic field using spherical elementary current systems**

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The method of spherical elementary current systems (SECS) has been successfully applied to derive ionospheric equivalent currents from ground magnetometer data. Its one-dimensional variant (1D SECS) is now introduced especially for situations with data available only from a chain of magnetometers. We compare equivalent currents obtained by the 2D and 1D SECS methods and by 1D Fourier method using synthetic 1D current models. Then we study real situations with data from a 2D (IMAGE) and 1D (MM210) magnetometer network. We show that the 1D SECS reveals the integrated eastward and westward current densities very reasonably compared to the 2D SECS, also during clearly non-1D situations. It also follows that the 1D SECS can be applied in a routine manner to replace the commonly used local electrojet proxies (local AL and AU indices) by a direct quantitative estimate of the ionospheric currents.
The diamagnetic effect of enhanced plasma pressure regions in the ionosphere and its effect on magnetic field modelling

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David Cooke
Air Force Research Laboratory, Hanscom AFB, MA

It is known that regions of high plasma pressure tend to expel part of the magnetic field threading it. This phenomenon is termed the diamagnetic effect of plasma. The underlying mechanism is that the sum of plasma and magnetic field pressure in a given volume tends to be constant in a stationary case. While its importance is recognised in outer space, the diamagnetic effect has been regarded insignificant in near-Earth regions, due to the strong and dominating geomagnetic field. We found that this is not justified when considering the data of high-resolution magnetic field missions. In particular, in the equatorial region strong density anomalies build up during the afternoon and evening hours.

CHAMP is the first satellite combining high-resolution magnetic field instrumentation with sensors for plasma diagnostics. On its orbit at about 400 km altitude it is crossing regularly the equatorial Appleton anomalies. Here we encounter electron number densities of more than 2x10^{12} m^{-3}. This causes at typical plasma temperatures of 2000 to 3000 K an expected diamagnetic effect of some 3 to 5 nT, which is fully consistent with the observed magnetic field depletion. Its appearance is independent of the conductivity conditions, thus showing up both at day and night-time.

All previous studies have not considered the modification of the ambient magnetic field by the plasma pressure. We are going to present the characteristics of the effect at F region level. Examples will be shown outlining how main field and lithospheric field modelling efforts, as well as on studies of the equatorial electrojet and the Sq current are affected. A procedure to correct for the diamagnetic effect is proposed.

Peculiarity of equatorial ionosphere anomaly in seismoactive period according to Champ Langmuir probe data

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Results of equatorial anomalies investigations according to Langmuir probe Champ data in relation with seismic occasions in North-East part of Asia continent is presented. Peculiarities of anomalies are appeared in day before the beginning of earthquake series 08.10.2001 (Kamchatka). The peculiarities are manifested in kind of electron density variations with space scale near 100 km and time duration up to 20-30 s. These effects are finished in day after EQ. These results may be interested in relation with global scale variations of ionosphere, related with EQ (Kalinin et al).

Wavelet modelling of low-latitude ionospheric currents and the induced magnetic field

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A multiscale approach for reconstructing equivalent toroidal ionospheric currents from given magnetic field data will be presented. The method is based on a multiscale technique for regularization of vectorial inverse problems. The equivalent spherical ionospheric current system and the corresponding magnetic field at satellite's height are connected via the singular system of the Biot-Savart operator. In this context a special system of vector spherical harmonics plays an essential role. By use of this system regularizing vector scaling functions and wavelets are developed to solve the ill-posed problem of reconstructing the current system.
The applicability and efficiency of the multiresolution technique, especially the possibility of space localizing reconstructions, will be illustrated with CHAMP FGM data as well as with simulated SWARM magnetic field data.

**A Comparative Study of Geomagnetic Pi2 Pulsations Observed by CHAMP and on the Ground**

Peter R Sutcliffe  
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Hermann Lühr  
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We present initial results of a comparative study of Pi2 pulsations observed by the CHAMP satellite and at the Sutherland ground station [32° 24’ S, 20° 40’ E]. Times when a Pi2 pulsation was observed on the ground (predominantly during night-time) and when CHAMP was located within 30° of longitude of Sutherland and at latitudes less than 50° N and S were selected for study. Following pre-processing and inspection to exclude unsuitable events, the satellite vector magnetic field data were rotated into a field aligned coordinate system and band-pass filtered in the Pi2 frequency band (typically .005 - .05 Hz). Initial findings to date are the following:

- The correlation between satellite and ground Pi2s is improved by subtraction of a lithospheric magnetic field anomaly model from the satellite data.
- The H-component signal on the ground is well correlated with the compressional (Bcom) and poloidal (Bpol) components above the ionosphere.
- Typical H-component amplitudes on the ground are 0.5 to 2 nT, while at CHAMP the Bcom and Bpol amplitudes are roughly 0.7 and 1.4 times this respectively.
- In the southern hemisphere Bcom and Bpol oscillate in phase with H; however, in the northern hemisphere Bpol appears to oscillate in anti-phase with Bcom and H.

**ULF wave magnetic measurements by CHAMP satellite and SEGMA ground magnetometer array: case study of July 6, 2002.**


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(4) Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences, Sopron, Hungary.

The CHAMP mission provides an interesting opportunity for a close comparison between ground and space ULF wave magnetic measurements. During June-July 2002 the satellite passed several times close to the south European ground magnetometer array SEGMA (1.56 < L < 1.88) on daytime hours. We present here the analysis of a Pc3 geomagnetic pulsation event observed simultaneously on space and at the ground array during the conjunction of July 6, 2002. Both compressional and transverse oscillations were identified in CHAMP magnetic measurements. A close correspondence between the compressional component and the ground signals is observed. The behavior of the CHAMP azimuthal component shows evidence for the occurrence of a field line resonance at L ≈ 1.6. The frequency of these azimuthal oscillations is about 20% higher than the frequency of both the compressional oscillation and the ground pulsations. Such a difference is explained in terms of a Doppler shift caused by the fast movement of the satellite across the resonance region where the phase signal changes rapidly. A further analysis verifies for the first time by space measurements the theoretical pattern of the wave polarization sense in the resonance region. The comparison with corresponding SEGMA measurements also provides an unprecedented direct confirmation of the well known 90° rotation of the ULF wave polarization ellipse through the ionosphere.
The Noon-Time Equatorial Electrojet: Its Spatial Features as Determined From CHAMP Satellite Observations.

Hermann Lühr, Stefan Maus, Martin Rother
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We present a comprehensive study of the noon-time equatorial electrojet (EEJ) based on more than 1000 passes of the CHAMP satellite. The low orbit of CHAMP and its high-precision magnetometers allow to reveal the spatial structure of the EEJ with unprecedented accuracy. Data from two and a half years have been used to investigate average features, but also the global characteristics of the EEJ. Special attention has been paid to a proper separation of the EEJ signature from magnetic effects of other current systems like Sq or ring current. In addition we take into account for the first time the diamagnetic effect of plasma pressure. Rather than interpreting the EEJ in terms of its magnetic signature we inverted the observations to obtain the equivalent current distribution in the E layer.

Some of the special features of the noon-time EEJ emerging from our analysis are: The eastward electrojet currents peak right at the dip equator. There is no deviation from it neither on a seasonal base nor with longitude. The width of the EEJ is well correlated with the peak current density. The intensity of the noon-time EEJ is rather variable. Day-to-day, but also orbit-by-orbit changes are very large. On average the EEJ intensity tracks well the level of solar flux, as indicated by the F10.7 index. The current strength exhibits a distinct variation with longitude. Clear peaks show up over South America and Indonesia. Our current profiles indicate the presence of return currents at the flanks. At certain longitudes they seem to be rather prominent.

Wavelet-parametrizations of the MIE-representation – Applications to ionospheric geomagnetic data

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The Mie-representation of the geomagnetic field and the corresponding electric current densities is a useful tool to approach the 'direct source problem' of calculating the magnetic effects of a given current distribution, as well as the 'inverse source problem' of calculating current systems corresponding to a given magnetic field. In order to cope with currents that vary rapidly with longitude or latitude, or that are confined to certain regions, parametrizations of the Mie-representation in terms of suitable trial functions need to be applied. We derive a wavelet-parametrization of the magnetic field in Mie representation which is able to reflect the various levels of space localization in form of a multiresolution analysis of both, electric currents and the magnetic field. The efficiency of the method is demonstrated by the multiscale reconstruction of radial current distributions from CHAMP-FGM-data.

Classes of Electrojet Signals

Heather McReadie
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Each day the CHAMP satellite passes over a current in the ionosphere called the equatorial electrojet. This current is in a narrow belt at approximately 108km above the surface of the Earth and generally flows in a westward direction. The Overhauser Magnetometer (OVM) on board CHAMP records a signal from this current for each pass. The normal signal has an inverted bell shape with the peak of the height of the bell occurring near midday. However, the OVM also records other signals for some passes. An algorithm has been developed that recognises four classes of signal from the electrojet. The classes are, the classical electrojet described already, the counter electrojet which has a bell shape that is not inverted, formation of the electrojet which is a combination of the classical and counter electrojet, and no electrojet. A brief description of each class and a statistical study on the location, period and corresponding magnetic events will be shown.
Space-time peculiarities of annual variation of geomagnetic field level and its possible source

Valentine Pogrebnoy

Space-time peculiarities of season changes of H, Z-components and declination D have been studied by using the data from 36 magnetic observatories (during 1964) situated consecutively in northern hemisphere every 1°-5° in range of latitude 4°-82°N. As a result, the annual variation of geomagnetic field level has been revealed. Its amplitude changes gradually approximately in a parabola from minimum in winter to maximum in summer. Annual variation does not depend on longitude, but has clear latitude dependence. The amplitude of annual variation is at maximum at high latitudes, and gradually decreases to naught at equator. Spherical harmonic analysis and constructed on its base equivalent current system have shown space-time peculiarities of annual variation of geomagnetic field level which have clear regularity and can be described by existence of particular current system. The eastward-directed current lines form loop around the pole, and extend over all summer hemisphere. Therefore, this current system can be called as circumpolar one. Maximum current intensity is at polar latitudes, and gradually decreases to naught at equator. The height of location of circumpolar current system can be determined only through satellite data. There are the first positive results on this subject, for example see: J.C. Cain, B. Ferguson, D. Mozoni “Satellite-based magnetic field modeling” and V.P. Golovkov, T.E. Zvereva, T.A. Chernova “Seasonal changes of geomagnetic field” , which were presented at the 4th Ørsted International Science Team (OIST-4) Conference Copenhagen, Denmark, 23-27 September 2002. However, it is required further, more detailed comparison of satellite and groundbased data for solution of this problem.

The E-layer electric fields above magnetic equator

Valentine Pogrebnoy, Timur Malosiev

The results of calculations of electric field above magnetic equator are presented. For that, the data of rocket investigation were used which were carried out during IGY and IYSS. For these calculations, it was chosen rocket launchings which measured concurrently both magnetic field values and electron density. 7 rocket launchings were analyzed which were executed in magnetic equator zone in 1965-1966 (minimum solar activity). The computations have shown that E-layer electric fields of ionosphere above magnetic equator have considerable changes both in height and time. The maximum value of electric field exists at a height of 110 km, where, at near-midday hours (minimum solar activity), electric field intensity amount to 4-10^4 V m^-1. At heights of 95 km and 140 km electric field intensity is 3-4 times less than at height of 110 km. At morning and afternoon hours the electric intensity is nearly half as many as at midday hours. The comparison of electric fields data, which were obtained by rocket launching at middle latitudes, has shown that electric fields at the magnetic equator are 10-100 times less than at middle latitudes. This result does not contradict to dynamo theory since according to this theory, electric fields, which causes Sq-current system, are generated at middle latitude and then magnetic equator are attenuated. This investigation was carried out with support from International Science and Technology Center (ISTC), Project KR-214.

Session M 6: Mission-related Topics & Session Summaries
Thursday, Sep 4, 2003, 16:00-17:30
Chair: Martin Rother

The swarm constellation: Mission concept and closed-loop system simulation

Nils Olsen, Eigil Friis-Christensen, Roger Haagmans, Gauthier Hulot, Herrmann Lühr, Stefan Maus, Michael Purucker, Terence Sabaka, Pascal Tarits, Alan Thomson

The swarm mission concept consists of a constellation of four satellites for studying the Earth's magnetic field and its interaction with the Earth environment. Each satellite will provide high-precision measurements of the magnetic field; in combination, they will provide the necessary observations that are required to separate the various sources of the geomagnetic field. GPS receivers, an accelerometer and an electric field instrument will provide supplementary information for studying the interaction of the magnetic field with other physical, quantities characterizing the Earth system. swarm has been selected by ESA for a Phase-A study. In parallel with this, a closed-loop simulation of the mission has started. The objective of this simulator is to separate the various contributions of the
geomagnetic field using realistic synthetic data – in much the same way that will be used regarding the real data – with the aim of evaluating various mission and constellation scenarios.

We will report on the swarm mission concept, on the various approaches used for the system simulation study, and on first results.

The ESPERIA space project: a mission for monitoring preseismic electromagnetic emissions and anthropogenic effects in the near-Earth space, and for defining the near-Earth magnetic environment.

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ESPERIA is an equatorial mission planned with a Low-Earth-Orbit small-satellite and a multi-instrument payload mainly devoted to study electromagnetic phenomena of natural and anthropogenic origin and perturbations and instabilities they produce in the near-Earth space. The space project has been proposed by an International Consortium lead by the University Roma Tre, for an electromagnetic, plasma, and particle mission mainly concerned with detecting any tectonic and preseismic related signals. The primary aim is to study ionospheric and magnetospheric effects caused by seismicity to develop methods for the evaluation of seismic risk (providing for disaster assessment) and give contribution in earthquake forecasting studies. A secondary objective of the mission is the study of electromagnetic emissions of anthropogenic origin (power line harmonic radiation, VLF and HF transmitters) and their influence in the ionosphere and magnetosphere. Other secondary objectives are the study of important phenomena, as equatorial electrojets and atmosphere-ionosphere-magnetosphere coupling effects during thunderstorm activity (sprites, blue jets, elves, gamma and electromagnetic emissions).

At present, a phase A study has been completed for the Italian Space Agency (ASI). To achieve the objectives with maximum reliability, the ESPERIA project is based with strong emphasis on coordinated, simultaneous, and continuous ground-based and space observations. On board the satellite ULF-HF electromagnetic fields, fluxes of charged particle (200 keV-GeV), and ionospheric plasma temperature and density will be detected. Ground-based measurements of mechanical (tilt and strain) and electromagnetic fields will be carried out in several test areas. The lacking of a geomagnetic field mission in an equatorial orbit, as well as similarities and complementarities of ESPERIA with respect to actual missions will be discussed. In particular, ESPERIA has the same main scientific objectives as DEMETER but the two missions also exhibit some interesting complementary aspects concerning orbit and multi-instrument payload. Moreover, the ESPERIA mission is planned for an equatorial orbit which would be critical in complementing the SWARM configuration. So, ESPERIA could be consider not a competitor to SWARM but an important potential partner for defining the near-Earth magnetic environment.

M 6 Posters (in alphabetical order)

The CHAMP ME Data Processing and Status of Level 2 Products

Martin Rother, Sungchan Choi, Wolfgang Mai, Hermann Lühr and David Cooke

The routine processing of the CHAMP data has started in May 2001. Since then calibrated data, (science quality) Level 2 products, are made available to the community through our data centre ISDC. The gained experience with the behavior of the instruments prompted some small adjustments of the processing codes. Also feedbacks from the users were considered when appropriate. In our presentation we will report on the availability and quality of the data on an instrument-by-instrument base. Within the Magnetic and Electric field (ME) group we process the scalar and vector magnetic field data, evaluate the star camera readings and the ion drift-meter measurements.
For a complete cross-calibration between the scalar and vector magnetometers twice dedicated attitude manoeuvres have been performed. A modified processing of the star camera readings has reduced the attitude noise during periods of single head solutions. As a rather recent product, we make the local electron density available. It is planned to estimate also the electron temperature. Both quantities are derived from the Planar Langmuir Probe.