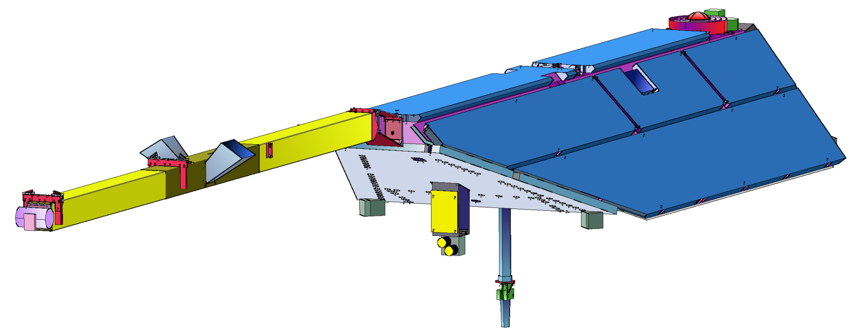

Magnetic field modelling with CHAMP data: initial results

GFZ POTSDAM

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Introduction

The CHAMP satellite was launched successfully at 11:59:59.628 UTC, July 15, 2000 from Plesetsk launch site, north of Moscow, with a Russian COSMOS launch vehicle. A major objective of the satellite's projected 5 year mission is to measure the geomagnetic field. While the mission is focused on collection of vector data, this data is not yet available for scientific study. Here, we use the magnetic field intensity measurements from the onboard Overhauser proton magnetometer. We present initial results relating to all parts of the magnetic mission – the main field, the lithospheric field, and the ionospheric and external fields.

Main field model

With only field intensity measurements it is not possible to produce a reliable main field model because of perpendicular error (Backus) effect. Instead, we compare the data against two recent main field models from Ørsted data. We examine the data misfit to these models (allowing a free determination of the external dipole), and then solve for a model which better fits the CHAMP data, but is close to the Ørsted model. Specifically, we seek a model that minimises

$$\sum_i (F(\mathbf{r}_i) - F_i)^2 + \lambda \int_{7150\mathrm{km}} (\mathbf{B} - \mathbf{B}_{\mathrm{mod}})^2 dS$$

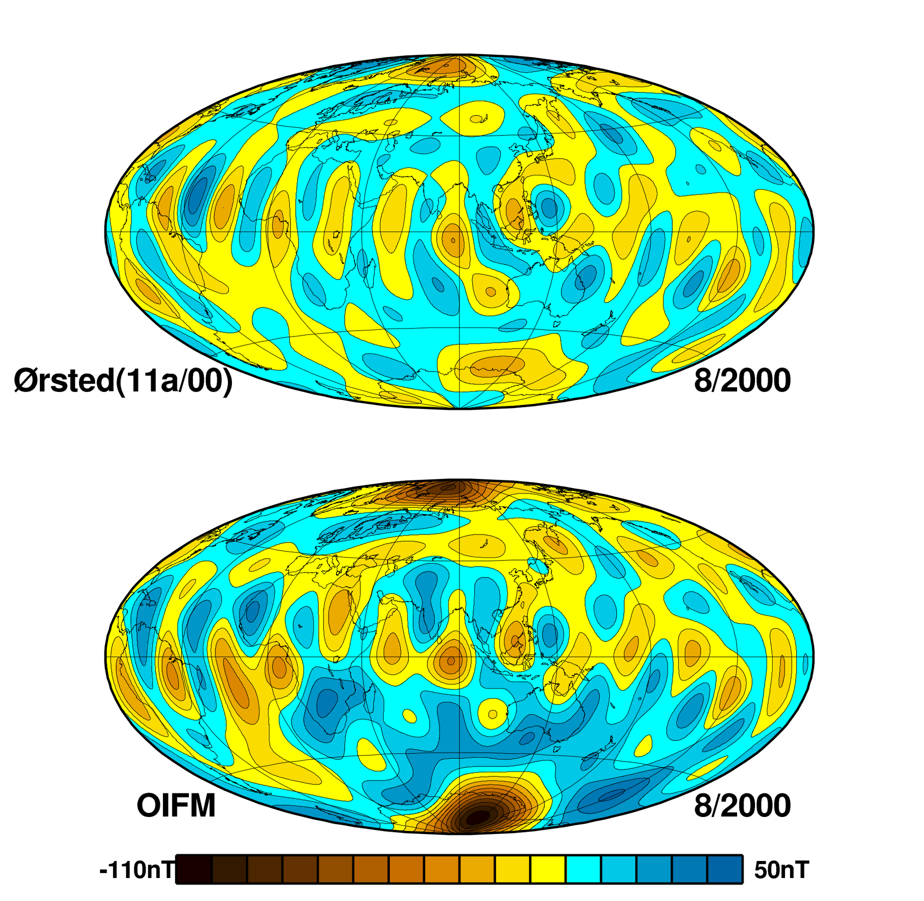
- First term – squared misfit to CHAMP data.
- Second term – mean square misfit to field model *at Ørsted altitude*
- Spherical harmonic potential field model, degree 13 internal, degree 1 external, no Dst dependence.
- Two Ørsted models:
  - Ørsted initial field model (OIFM) (Olsen *et. al.*, 2000).
  - Ørsted(11a/00) – poster GP61A-04, this session.
- Apply secular variation correction from epoch 2000.
- λ trade-off parameter – preferred solution chosen at sharp "knee" in trade-off curve.
- Focus on results for 8/22-8/25, Kp $\leq 1+$:

Model used	OIFM		Ørsted(11a/00)	
Model misfit	–	8.68nT	–	3.25nT
Data misfit	14.9nT	5.0nT	7.4nT	5.0nT

- First column for original Ørsted model, second column for fit to CHAMP data.
- Data fit by new Ørsted model better than by OIFM.
- Principal misfit from OIFM at south pole – model contamination from summer ionospheric currents?
- External dipole (q_1^0) more reasonable with Ørsted(11a/00) (21nT) than with OIFM (30nT) – external field parameter tries to compensate for large residuals near south pole.

How do the CHAMP data change the Ørsted models? Difference between input and output models at Earth's surface:

Z CPT CHAMP - ØRSTED MODEL DIFFERENCES

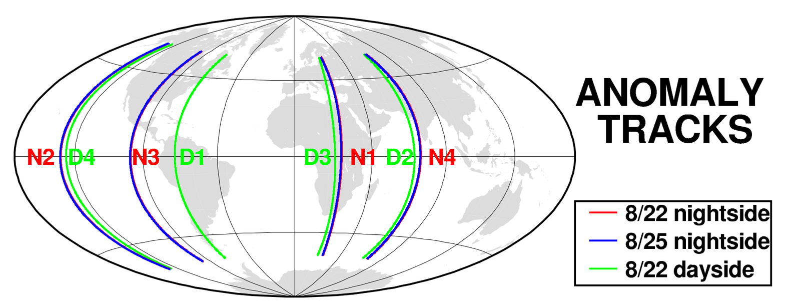


- Ørsted(11a/00) differences mainly small scale - truncation effects
- Larger scale OIFM differences due to (a) problems near south pole, (b) less accurate secular variation model

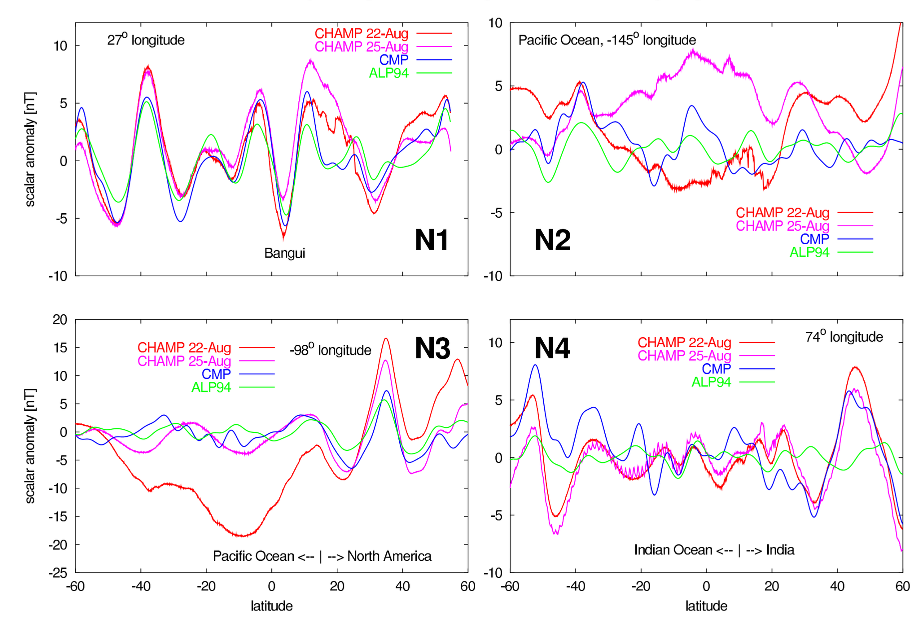
Conclusion: CHAMP data provide strong confirmation of the quality of the models from Ørsted data.

Magnetic anomaly tracks

We do not yet have enough quiet-time data to constrain models of sufficiently high degree and order to model the lithospheric field (degrees 14 and above). Instead, we subtract the modelled main field from night time data, and compare the residual with two global models of the long-wavelength lithospheric field obtained from Magsat and POGO data. These are ALP94 (Arkani-Hamad *et. al.*, 1994) and CMP3 (Sabaka *et. al.*, 2000). This comparison is made particularly robust by the fortunate chance that in August 2000, CHAMP was on a 3-day (almost) exact repeat orbit, with repeat tracks separated by only 0.4° in longitude. The tracks are shown below; the two nightside tracks (in red and blue) are almost indistinguishable. The comparison of repeat tracks provides information on CHAMP data quality.



NIGHTSIDE ANOMALY TRACKS



A DC shift is removed from some comparisons.

N1: Extending from S. Africa to Finland. Good agreement between repeat tracks and both of the field models. Note the strong signature of the Bangui anomaly.

N2: From the Pacific to the coast of Alaska. Disagreement between the repeat tracks, perhaps related to different values of Dst, although the global field models also disagree.

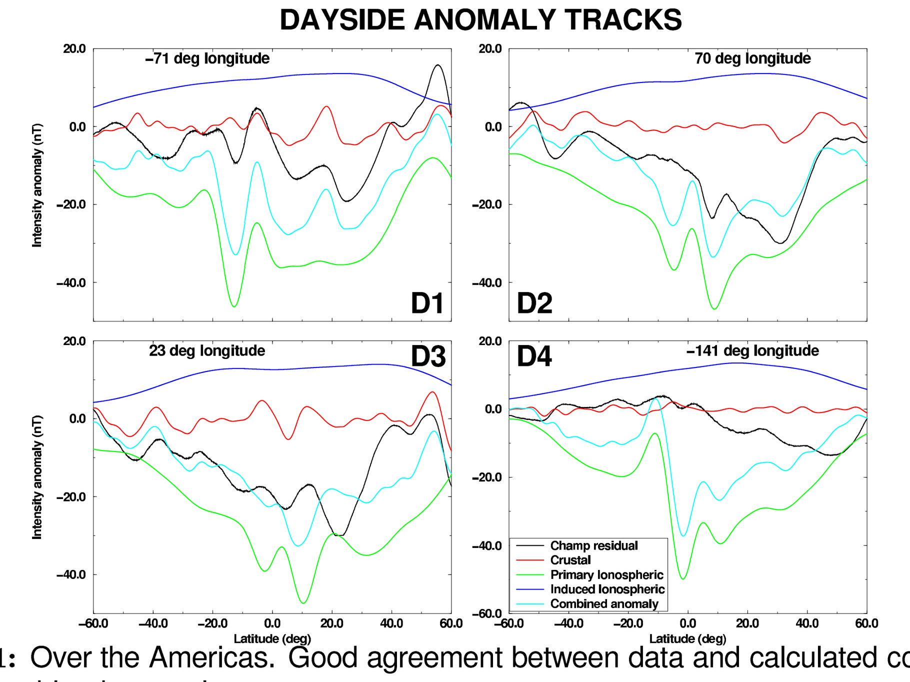
N3: Further East, from the Pacific ocean into Mexico. From poor agreement over the Pacific ocean into reasonable agreement over land.

N4: A track over the Indian Ocean extending into Asia shows good repeatability and reasonable agreement with CMP3. Interestingly, ALP94 misses a prominent anomaly in Siberia.

Modelling dayside data

Dayside data is typically ignored in main and crustal field modelling, due to contamination from ionospheric fields. However, the CMP3 model attempts to model this contribution directly. The model contains a spatial and temporal parameterisation of the fields, modulated by a solar activity index. We calculate the prediction of this model and compare it to CHAMP dayside data. For four tracks (shown in green on the map above) we display the individual contributions from the crustal field, the ionospheric field and the induced field from the ionospheric field, and compare their sum with the measured data.

DAYSIDE ANOMALY TRACKS



D1: Over the Americas. Good agreement between data and calculated combined anomaly.

D2: Central Asia and the Indian ocean. Calculated ionospheric field provides a good model of the trend, and predicts one observed small scale anomaly (and two that are not observed!)

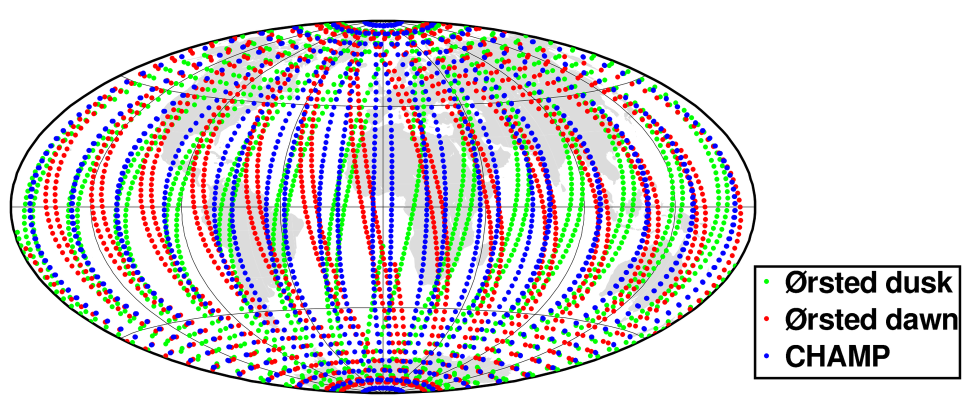
D3: Over Africa and Europe. Trend predicted by the ionospheric field. Small scale structure better explained by crustal field model alone than by the combined calculated anomaly.

D4: Over the Pacific. Not very good! (As for the nightside tracks).

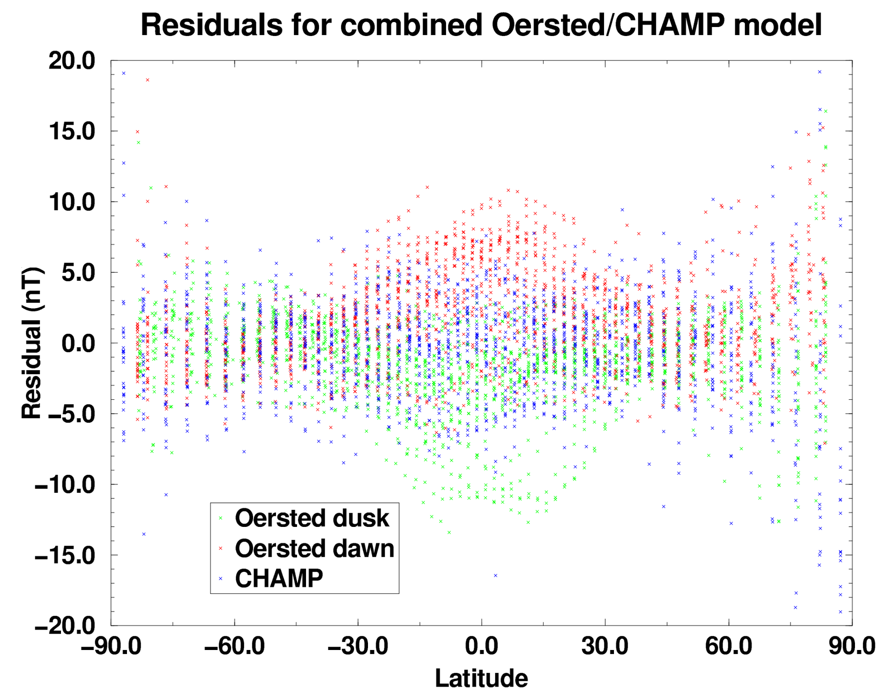
Simultaneous modelling of CHAMP and Ørsted data

In August 2000, Ørsted was in a dawn-dusk orbit. This allows us to compare dawn-dusk data (as collected by Magsat, for example) directly with night-time data (normally preferred for field modelling).

Available data distribution for this period:



We calculate a model as above, but with additional Ørsted data from the same period. Model residuals as a function of latitude:



Statistics:

	All data		$\lvert$Latitude$\rvert < 60°$	
	Mean	RMS	Mean	RMS
Ørsted dusk	-1.5nT	3.7nT	-1.8nT	3.6nT
Ørsted dawn	1.9nT	4.0nT	2.0nT	3.9nT
CHAMP	-0.3nT	5.2nT	-0.11nT	3.1nT

- Clear difference between Ørsted dawn and dusk residuals, with CHAMP residuals approximately zero mean. Same difference seen if CHAMP data are not used in model.
- CHAMP residuals worst near poles (close to ionospheric current systems), Ørsted near equator.
- Evidence for asymmetric ring current?

Conclusion: Detailed matching of the CMP3 predicted field and the observed values would be surprising, as (for example) external fields are treated inconsistently between CMP3 and our main field model. Nevertheless, CMP3 shows strong potential to aid understanding of the CHAMP-observed magnetic field, although the fit is not good enough to suggest subtracting modelled ionospheric field contribution from the data.

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Acknowledgement

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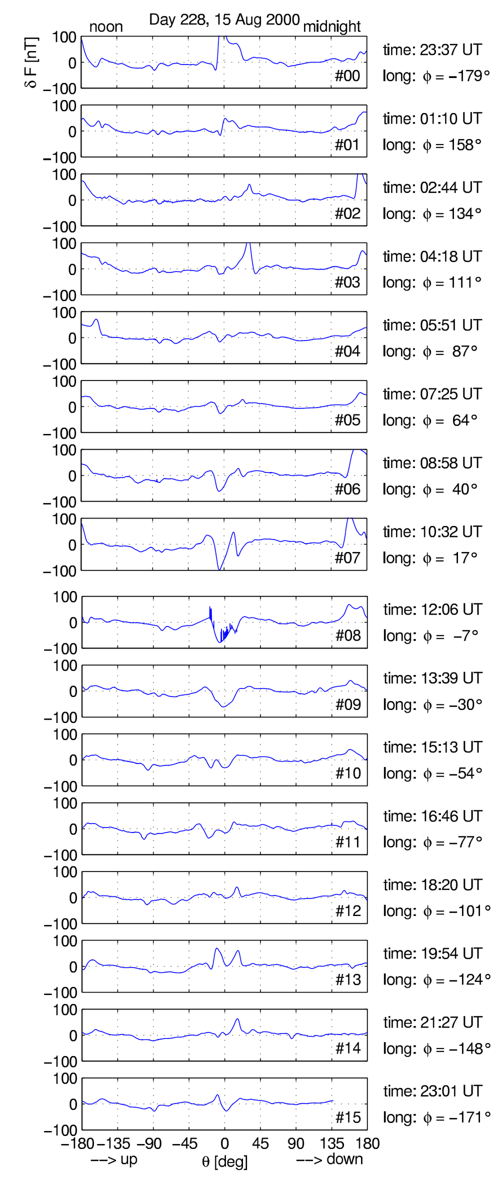
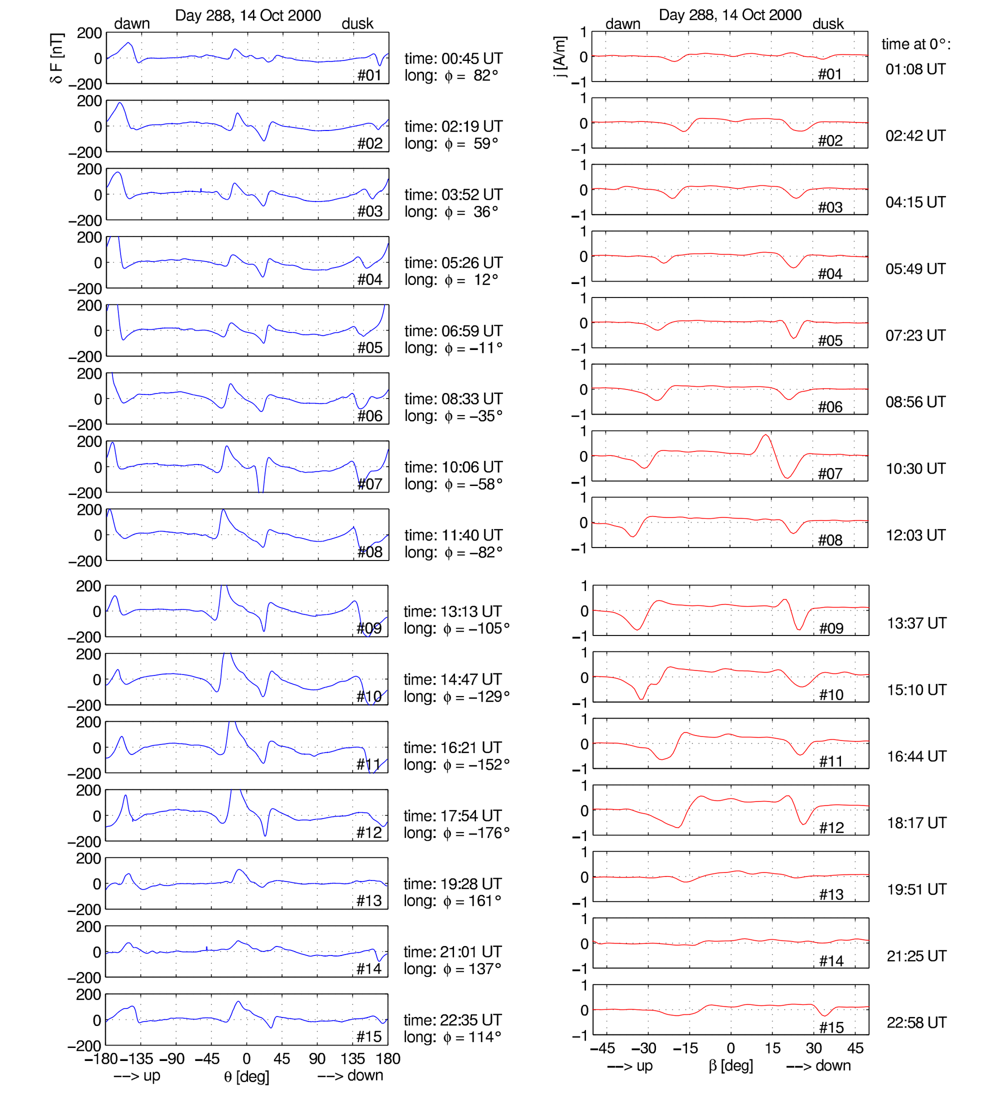
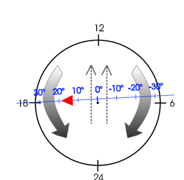
Studying Ionospheric Currents

A significant part of the magnetic field measured on board of low-Earth orbiting satellites is caused by currents in the ionosphere. These magnetic signatures may conversely be used to estimate the actual current configuration. In this study we concentrate on the interpretation of the magnetic field magnitude and thus can make no statements on the field-aligned current distribution. For the interpretation of magnetic signatures of ionospheric currents we first subtract a main field model of degree and order 13 (OIFM, Olsen et al., 2000) from the magnetic field readings sampled by CHAMP and furthermore apply a D_{st} correction. The obtained residuals are subjected to an inversion algorithm similar to the one proposed by Olsen (1996) for computing the ionospheric currents. A series of line currents at E region heights (110 km) is used to approximate the actual current configuration. The figure to the right shows the residual (external) magnetic field for the 15 orbits of 15 Aug 2000. On this day CHAMP was on a noon/midnight orbit. The individual tracks start at the south pole, ascend over the day-side to the north pole (middle of the panels) and continue south bound over the night-side. Time and longitude of the ascending node are indicated at the right side. Most prominent, as expected, are the signatures in the polar regions. Interesting feature, although much smaller, also show up at lower latitudes. One of these is the equatorial electrojet (EEJ) close to the day-side equator. There is no such current on the night-side.







Another set of external field tracks dates from 14 Oct 2000. On this day CHAMP was on a dawn/dusk orbit. In this time sector we see rather coherent magnetic signatures at high latitudes over the whole day. Only the amplitude of the deflections is varying from orbit to orbit. There is furthermore an anti-symmetric variation between dawn and dusk at low latitudes. This is probably caused by an asymmetric ring current. In this meridial plane there is no clear signature of the EEJ. Adjacent to the magnetic field tracks we have plotted the estimated ionospheric current distribution (predominantly Hall currents) within the northern high latitude regions. As a prominent feature we find enhanced negative current densities on the dawn and dusk side some 20 deg away from the poles. Over the polar cap there is a small although persistent positive current density.

The observed ionospheric current configuration is sketched in the figure below. CHAMP is passing the polar cap 2.7 deg sunward of the geographic pole. The two prominent negative peaks in current density can be associated with the polar electrojets (PEJ) flowing anti-sunward on the dawn and dusk side. Within the polar cap the sunward return current is a much fainter.

As a next step we will compare these results with current estimates from ground- based observations for verification and for the determination of the associated induction effects.

Conclusion: CHAMP magnetic field measurements are well suited for ionospheric current estimates. It is planned to generate a satellite-based magnetic activity index.