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Investigation of decadal scale changes in the auroral oval positions using Magsat and CHAMP data

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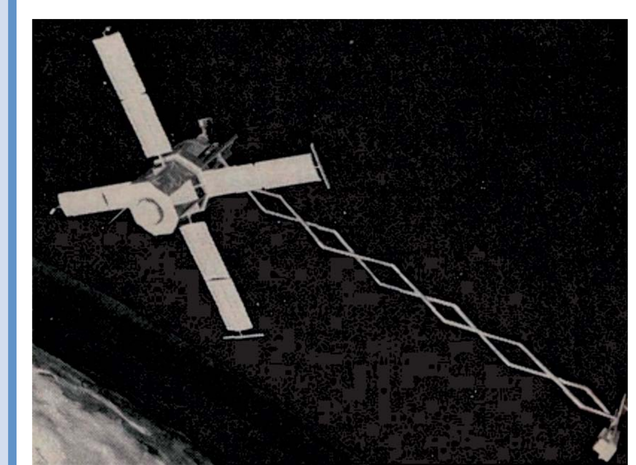
Introduction

The magnetic field sources inside the Earth play an important role in determining the long-term patterns in space weather and influence the magnetic field variations from sources external to the Earth. For example, current systems in the auroral region, which produce large magnetic disturbances during sub-storms, are strongly ordered by the Earth's main magnetic field which are connected via that field to interactions with the solar wind high in the magnetosphere.

It has been known for some time that geodynamo processes in the Earth's fluid outer core result in changes in the magnetic field, known as secular variation, that are most visible on decadal and longer time-scales. Observatory measurements over the past two centuries suggest the dipole moment has decreased by over 10% in that period. Some changes of the non-dipolar field are seen to vary even more rapidly. For example, the north dip-pole has shifted hundreds of kilometres over the past century and with increasing speed over the past two decades.

We present the results of a search for decadal changes in the latitudinal extent of the auroral current system over the satellite era using a combination of Magsat (1979-80) and CHAMP (2000-10) magnetic data. One advantage of using these satellite data is that their polar orbits have excellent latitudinal resolution, which will help fix the extent of the auroral current systems.

Magsat & CHAMP data



Magsat

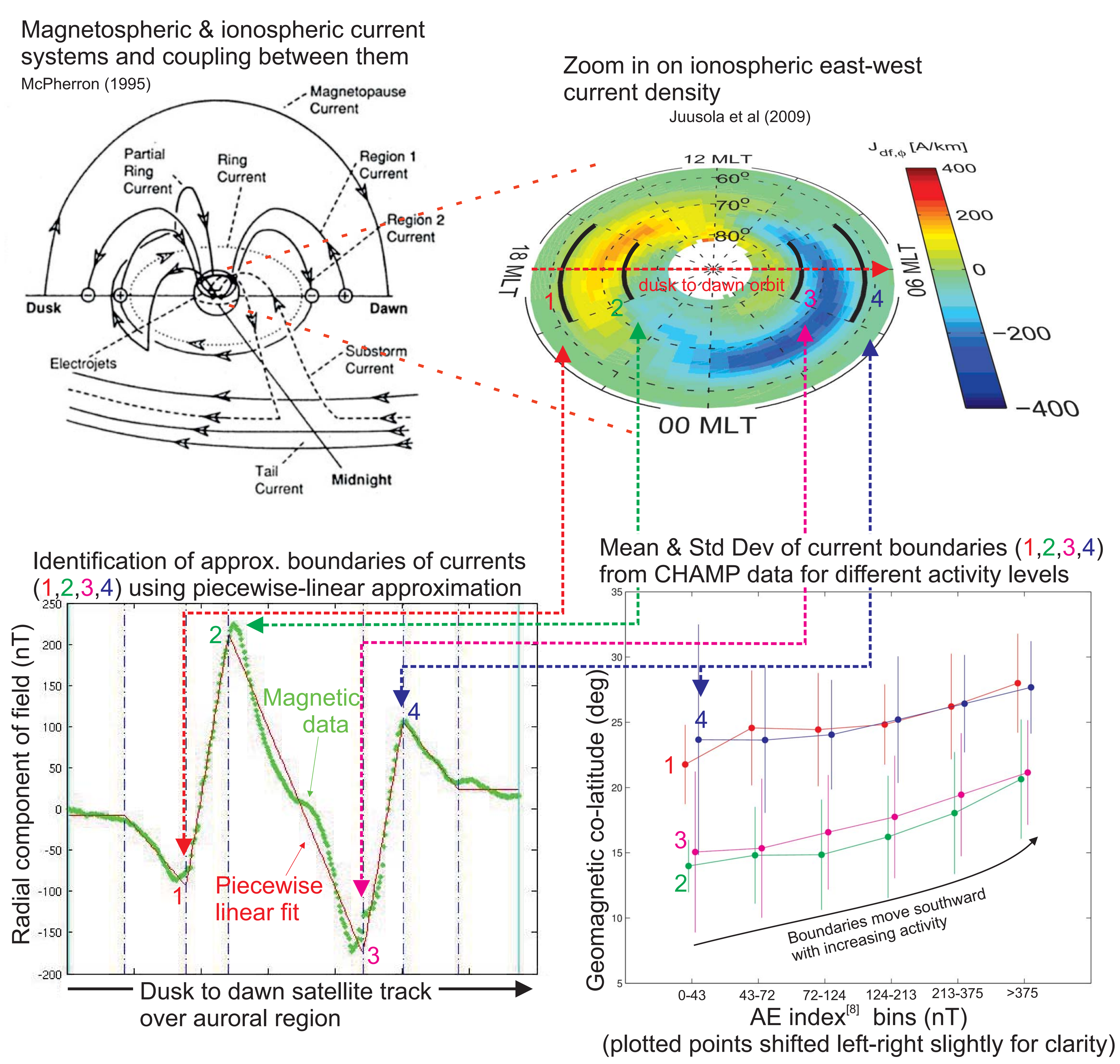
CHAMP

Magsat was launched in Autumn 1979 into a slightly elliptical polar-orbit between 350 and 550 km. Onboard were scalar and vector magnetic field instruments that operated until the end of the mission in Spring 1980. Magsat's orbit was sun-synchronous and only sampled dawn-dusk local times.

CHAMP was launched in Summer 2000 into a near circular polar-orbit, initially at 450 km altitude that decayed over the course of the 10 year mission until it deorbited in Autumn 2010. Unlike Magsat, CHAMP's orbit precessed over the course of the mission, repeatedly sampling all local-times.

All available data from Magsat was used for this study but to compare like-with-like, CHAMP data was selected only for the same dawn-dusk orbits as Magsat. From these data we attempted to identify the locations of the auroral currents and look for differences between the Magsat and CHAMP eras.

Identifying the auroral current systems



In the auroral regions, magnetic disturbances detected by ground observatories or low altitude satellites such as Magsat and CHAMP, can reach hundreds of nanotesla. These disturbances are caused by currents in the ionospheric part (approx. ≥ 100 km altitude) of circuits that extend far into the magnetosphere (top-left image[1]).

The top-right image shows a map of the horizontal ionospheic currents in the northern hemisphere produced from CHAMP data[2]. Our Magsat and selected CHAMP data will sample the magnetic field from these currents once each orbit. However, the data will also contain signals from the Earth's core, crust and magnetosphere. We therefore remove the *core field* signal using the 11th version of the International Geomagnetic Reference Field (IGRF-11[3]), and remove an estimate of the large scale *magnetospheric field* signal produced from the mid- and lower-latitude part of each orbit using code developed by BGS for the ESA Swarm satellite mission[4,5].

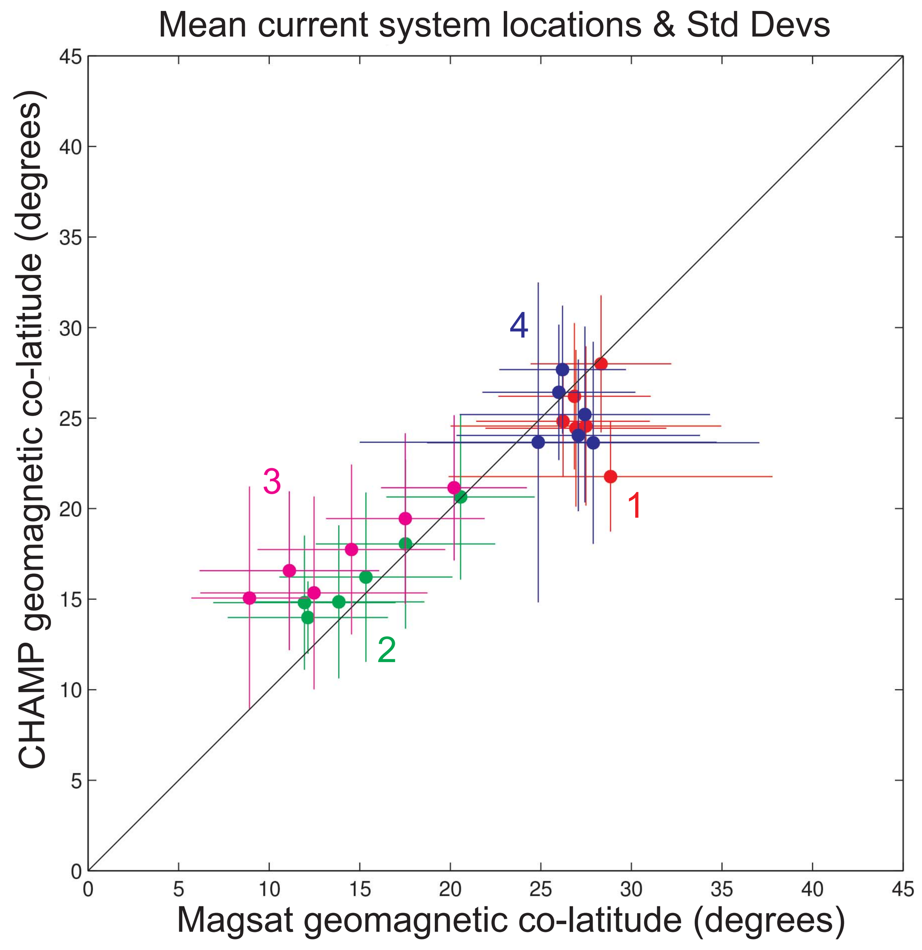
The bottom-left image shows a favourable example of a clean auroral current signature in the radial magnetic field detected by CHAMP during one northern-hemisphere transit (approx. dusk to dawn). We can use this curve to estimate the latitudinal extent of the auroral current system by fitting a piecewise linear approximation (thin red lines on bottom-left image) using spline-fitting software[6,7]. The software allows us to set limits on the gradients of each linear segment thereby search each track of data for the characteristic shape of the current system. The locations of each segment boundary are not fixed but are free to be fit by the code. Thus, these boundaries can be used to estimate the approximate latitude extent of the current systems (see 1,2,3,4 in bottom left and top-right images) in a consistent way between Magsat and CHAMP data.

Since most tracks of data will not be as clean as the one shown, we perform a quality check that reject fits that do not conform to the prescribed shape or where the signal-to-noise ratio (range of radial field : RMS residuals of fit) is below 15. We also retain only boundary locations where the data were collected within the range of altitudes common to both satellites. This is to reduce any differences in location resulting from the different orbit altitudes.

Note, the location of the auroral oval is also strongly influenced by short-term fluctuations in solar wind parameters that are independent of the long-term trends we are searching for. Therefore, to avoid this short-term activity obscuring our results, we partition the calculated co-latitues using the Auroral Electrojet (AE) Index[8] and then use the range of latitudes in each partition to estimate the error (c.f. bottom right plot for CHAMP).

Change in auroral oval position?

This plot shows computed Magsat vs CHAMP auroral current locations (1,2,3,4 see images above). For each location (colour) the mean (dot) and standard deviation (bars) over each activity range are shown. The number of successful fits per point range from 10's to 100's. The black line represents equivalence between Magsat and CHAMP locations (in geomagnetic latitude). It can be seen that lower latitude boundaries (1 and 4) tend to be further south for Magsat than CHAMP but for the inner boundaries (2 and 3) the situation is reversed. However, it should be noted the spread in values making up each mean location is quite large.



Conclusion

Our analysis suggests some systematic differences in the estimated latitudinal extent of the northern auroral current measured by Magsat and CHAMP, 20-30 years apart. However, the spread in computed latitudes ('errors') is quite large and the need to fit the characteristic magnetic signature has significantly reduced the number of viable satellite tracks for the comparison. It is possible that differences in the quality of the IGRF-11 main-field model between two eras could be influencing the results. However, our results show that further investigation using a more robust and consistent isolation of the ionospheric signal is warranted to determine if decadal scale changes in the auroral oval are visible in satellite data.

References

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