Substorm Timing and Location With the Combined CARISMA and THEMIS GBO Magnetometer Arrays

D.K. Milling, I.R. Mann, I.J.Rae and A. Kale

University of Alberta

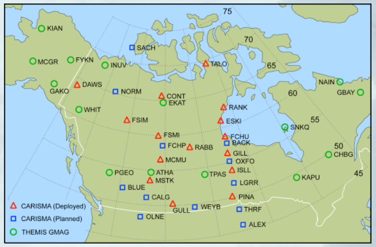
Abstract

The growing array of ground-based magnetometers deployed in North America will provide important substorm location and timing information in support of the THEMIS mission objectives. We present our plans to use the expanded CARISMA array together with the THEMIS GBO magnetometers to produce data products cataloguing the substorm onset time and estimated location of the substorm current wedge. A Pi2 detection algorithm [1] will be applied to the real-time CARISMA data to generate a database of substorm onset events. Subsequent analysis of the associated Pi1B pulsations across the combined array should allow substorm onset timing to within an accuracy of 10 seconds. We also propose to apply the York substorm location modeling algorithm [2] to produce initial estimates of the locations of the upward and downward field aligned currents and the Westward electrojet. The timing and location results will be published on the Canadian Space Science Data Portal.

[1] Nose et al., Earth Planets Space, *50*, 773-783, 1998

[2] Cramoysan et al., Ann. Geophys., *13*, 583,1995

Magnetometer Arrays

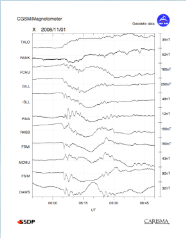


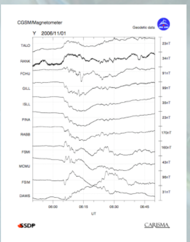
The map above shows the location of the magnetometers in the Canadian CARISMA array and the US THEMIS GBO array. The CARISMA array has 15 operational magnetometers as shown by the red triangles. A further 4 will be deployed in the summer of 2007 with another 9 to follow starting in 2008. The THEMIS GMAG magnetometers were deployed as part of the GBO program. The 15 GBO sites indicated in the map in fact also comprise magnetometers from the Alaskan Geophysical Institute (GAKO and FYKN), Athabasca Geophysical Observatory (ATHA and INUV) and NRCan (SNKQ).

The data from 5 of the CARISMA sites is decimated to 2 Hz and transferred to UCB to form part of the THEMIS GBO data set. In return the data from the rest of the GBO network is mirrored at the University of Alberta.

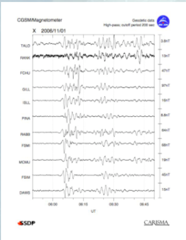
The combination of THEMIS GBO and CARISMA provides an extensive data set to which we can apply the data processing tools which are being developed to provide substorm location and timing information to meet the requirements of the THEMIS project.

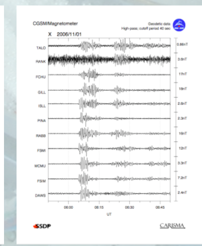
Substorm on 01 November 2006:





A Substorm onset was observed by CARISMA on 1 November 2006 at approximately 06:04 UT. The onset is seen across the array and the pattern of variation in the X and Y component "bays" indicates that the onset meridian is located within the longitudinal extent of the magnetometer network.

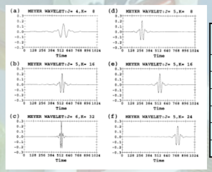




The plot on the left results from the application of a high pass filter at 200 seconds to the X component data and shows the Pi2 pulsations seen across the array. Visual identification of the substorm onset time is possible to within 1 or 2 minutes. The plot on the right shows the data after application of a high pass filter at 40 seconds and shows the pulsations in the Pi1 band. As these are higher frequency pulsations it should be possible to identify substorm onset with greater accuracy.

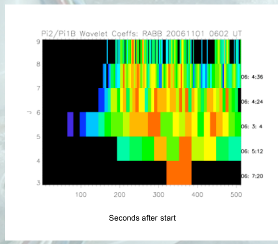
A method which avoids the subjective nature of attempting to time substorm onset visually from magnetograms is discussed in the next panel.

Substorm Timing by Wavelet Analysis

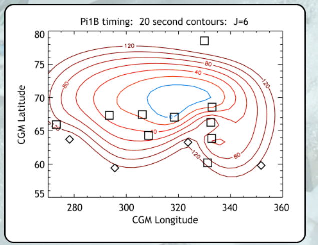


J	Period Range (s)	Band	Time Res (s)
9	6-1.5	Pi1	2
8	12-3	Pi1	4
7	24-6	Pi1	8
6	48-12	Pi1	16
5	100-24	Pi2/Pi1	32
4	200-48	Pi2	64

The analysis of a time series by application of the wavelet transform yields information about the frequency content of the signal as a function of time. We use the Meyer analyzing wavelet to explore the frequency content (J) and time shift (K) of those frequencies in magnetic field data.

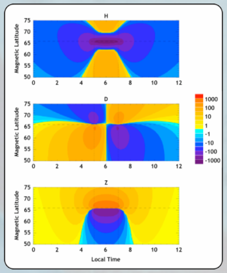


The results of the wavelet transform indicate that signals in the Pi1 period range of 48-12 seconds (J=6) arrive at the location before the Pi2 (J=4,5) is seen. Note that a threshold of 10dB above the pre-existing 'noise' level has been applied to the wavelet coefficients to enable an onset time to be defined in each band.



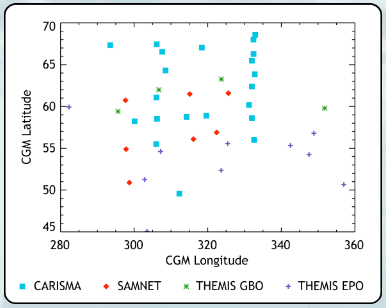
The J=6 arrival times at CARISMA (squares) and THEMIS GBO (diamonds) sites are shown here in a contour plot of times relative to 06:03:04 UT (blue contour). The results indicate propagation of the Pi1 signal from a region in the centre of the array. This can be defined as the substorm onset time.

Substorm Location Modeling



This plot shows the ground magnetic field response to the York substorm current wedge (SWC) model of Cramoysan, Bunting and Orr (1995). The response of an array of ground magnetometers can be analyzed to find the SCW location parameters which provide the best fit to the data. The fitting of component pair correlations across the array avoids the need to define baselines from which to measure the bay response.

This modeling technique has previously been successfully applied to study substorm onsets in the European sector using the SAMNET array. This sub-auroral array was ideally located for the technique in that the data are not significantly contaminated by electrojet noise which can make it difficult to obtain a good fit of the model to the data.



The map above shows the CARISMA magnetometer locations with a subset of THEMIS GBO and EPO magnetometers plotted in CGM coordinates. The red diamonds indicate the magnetic locations of the SAMNET array shifted 220° West. It can be seen that both the location and the separation of the CARISMA and THEMIS magnetometers yield an array which is capable of improved substorm location modeling results compared with previous work.

We plan to implement the York substorm modeling code at the University of Alberta as part of an integrated substorm timing and location package. The results will be made available on the Canadian Space Science Data Portal (www.cssdp.ca).