Statistics of Flow Channels Observed as Regions of Ion Heating in Energetic Neutral Atom Images

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Abstract

Reconnection in the magnetotail transfers magnetic energy to thermal and kinetic energy in ions and electrons. These particles are injected both Earthward and tailward from the reconnection region. The Earthward particles are transported to the inner magnetosphere where they drive the ring current and radiation belts. The injections are observed in the plasma sheet in conjunction with dipolarizations of the magnetic field. The particles have been found to travel within narrow flow channels, rather than broadly across the magnetotail, in spatially and temporally localized events known as bursty bulk flows (BBF). Simulations of such events show these narrow flow channels moving from the reconnection region to the injection region. However, global observations are needed to understand how BBFs connect the reconnection region and the inner magnetosphere during storms and substorms. Ion heating has been observed with in situ measurements at the reconnection region and within the dipolarization fronts and BBFs. Using energetic neutral atom (ENA) imaging, ion temperature maps can be calculated to provide such global observations. Regions of ion heating have been observed in these maps and comparisons with in situ measurements demonstrate that they are associated with these phenomena. An automated identification algorithm has been developed and run on our database of storm-time ion temperatures. We will present the results of case and statistical studies of the characteristics of these features.

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Introduction

Reconnection in the magnetotail transfers magnetic energy to thermal and kinetic energy in ions and electrons. These particles are injected both Earthward and tailward from the reconnection region. The Earthward particles are transported to the inner magnetosphere where they drive the ring current and radiation belts. The injections are observed in the plasma sheet in conjunction with dipolarizations of the magnetic field. The particles have been found to travel within narrow flow channels, rather than broadly across the magnetotail, in spatially and temporally localized events known as bursty bulk flows (BBF). Simulations of such events show these narrow flow channels moving from the reconnection region to the injection region. However, global observations are needed to understand how BBFs connect the reconnection region and the inner magnetosphere during storms and substorms. Ion heating has been observed with in situ measurements at the reconnection region and within the dipolarization fronts and BBFs. Using energetic neutral atom (ENA) imaging, ion temperature maps can be calculated to provide such global observations. Regions of ion heating have been observed in these maps and comparisons with in situ measurements demonstrate that they are associated with these phenomena. An automated identification algorithm has been developed and run on our database of storm-time ion temperature maps. We will present the results of case and statistical studies of the characteristics of these features.

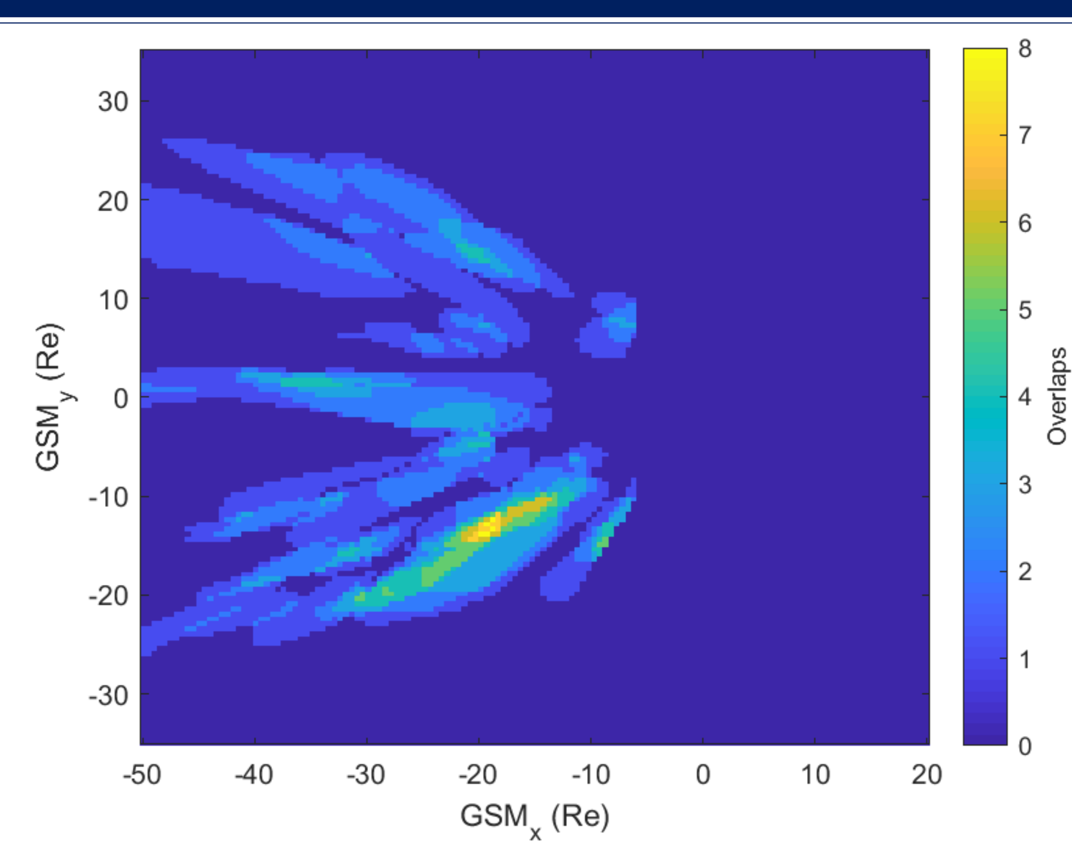
Methodology

A database of equatorial ion temperature maps has been calculated from TWINS energetic neutral atom (ENA) data. The maps are in GSM coordinates with bin sizes of 0.5 × 0.5 R_E. Geomagnetic storms of at least moderate intensity during the lifetime of the TWINS mission (July 2009-December 2017) are included in the database. They were selected using the Disturbance storm time (Dst) index from the Kyoto database with minimum Dst ≤ -60 nT. TWINS data with a 10-minute time cadence over a four-day window (starting the day prior to the day on which the minimum Dst occurred) were analyzed to provide pre-storm conditions as well as complete coverage of the main and recovery phases of the storm. The database is available in cdf format on CDAWeb.

We are developing an automated detection algorithm to select regions of enhanced ion temperatures in the magnetotail in these ion temperature maps. The regions are likely to be associated with phenomena such as magnetic reconnection, bursty bulk flows/flow channels, and dipolarization fronts based on previous (e.g. *Keesee et al*, 2014) and ongoing studies.

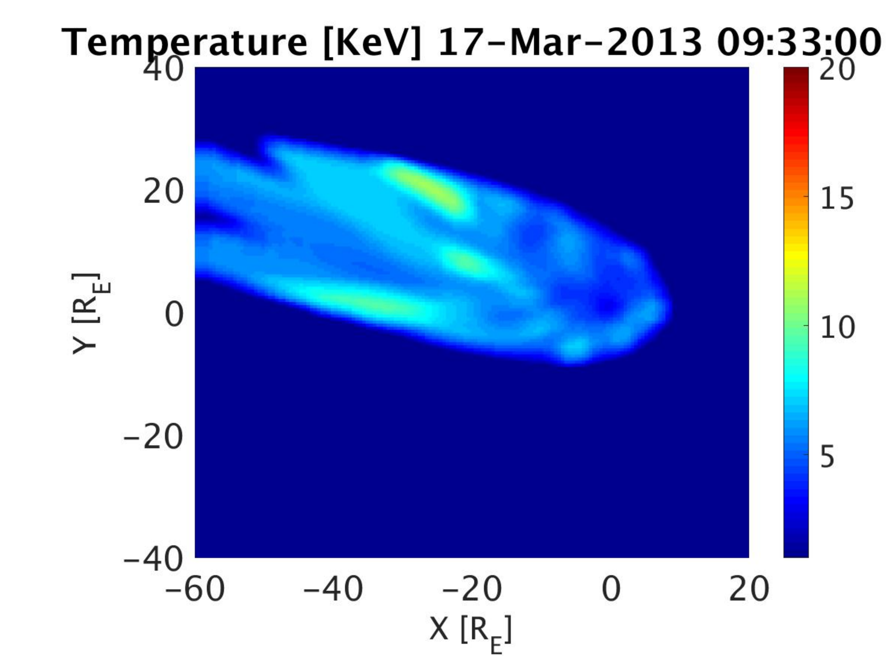
We plan to apply statistical analysis to the identified regions to learn more about their general characteristics. We selected intervals with enhanced temperature regions from two storms and calculated temperature maps at a ~3 minute cadence. We analyzed several features of the enhanced regions in these temperature maps for an initial test of our developed codes.

Regions of temperature enhancement

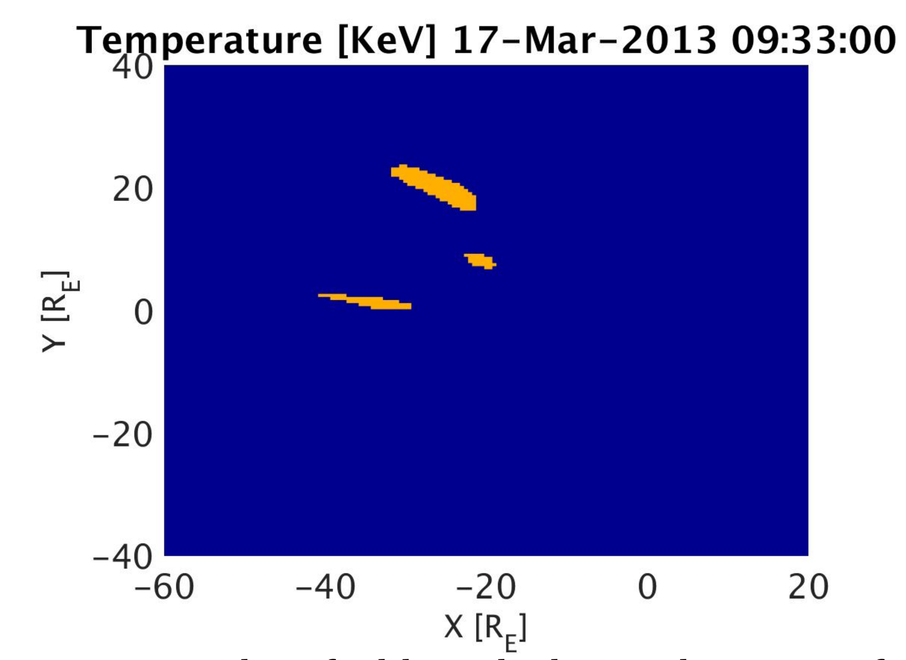


All of the identified regions of ion temperature enhancement from the test set of intervals overlayed on one plot.

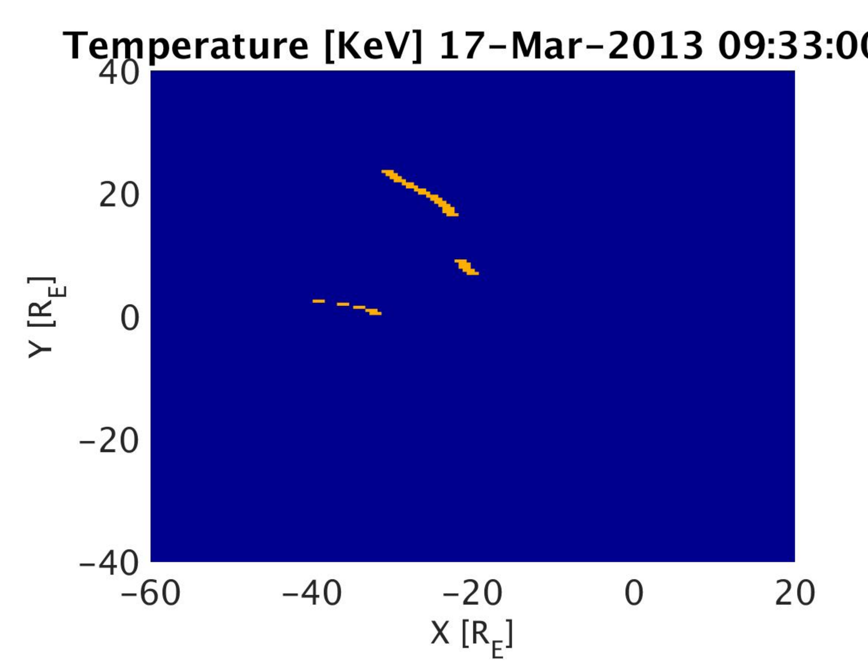
Automated Detection Algorithm



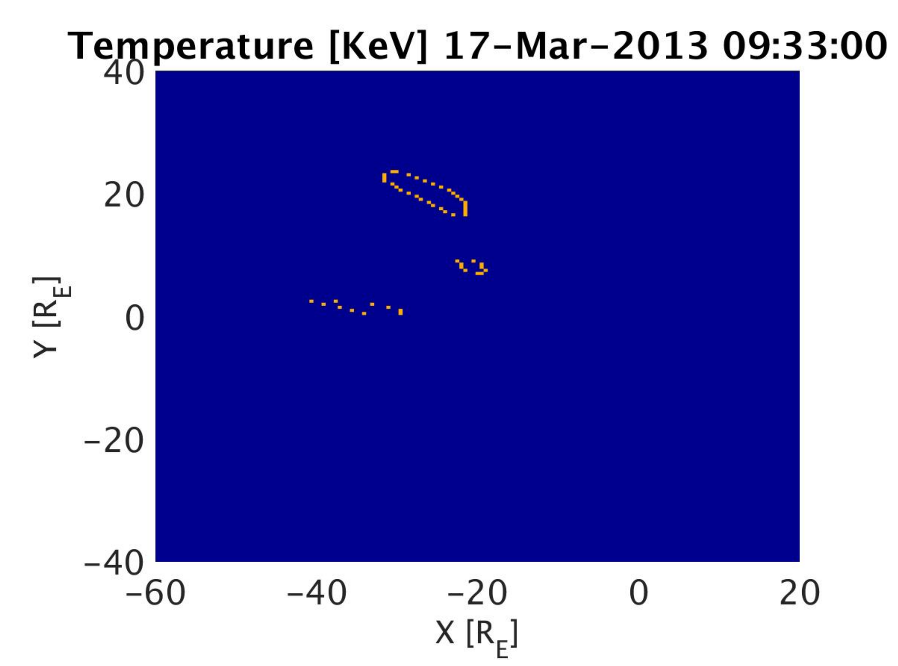
Equatorial ion temperature map calculated from TWINS ENA data. The temperature is calculated from a 2-sweep average of the flux data starting at 09:33 UT on 17 March 2013. The map is in GSM coordinates. Three regions of enhanced ion temperatures are observed in the magnetotail.



The regions are identified by calculating the mean of the ion temperatures in the plasma sheet identified by the region -60 R_E < x < -5 R_E and 2000 < MLT < 400 and marking pixels that are at least 2 standard deviations above the mean.



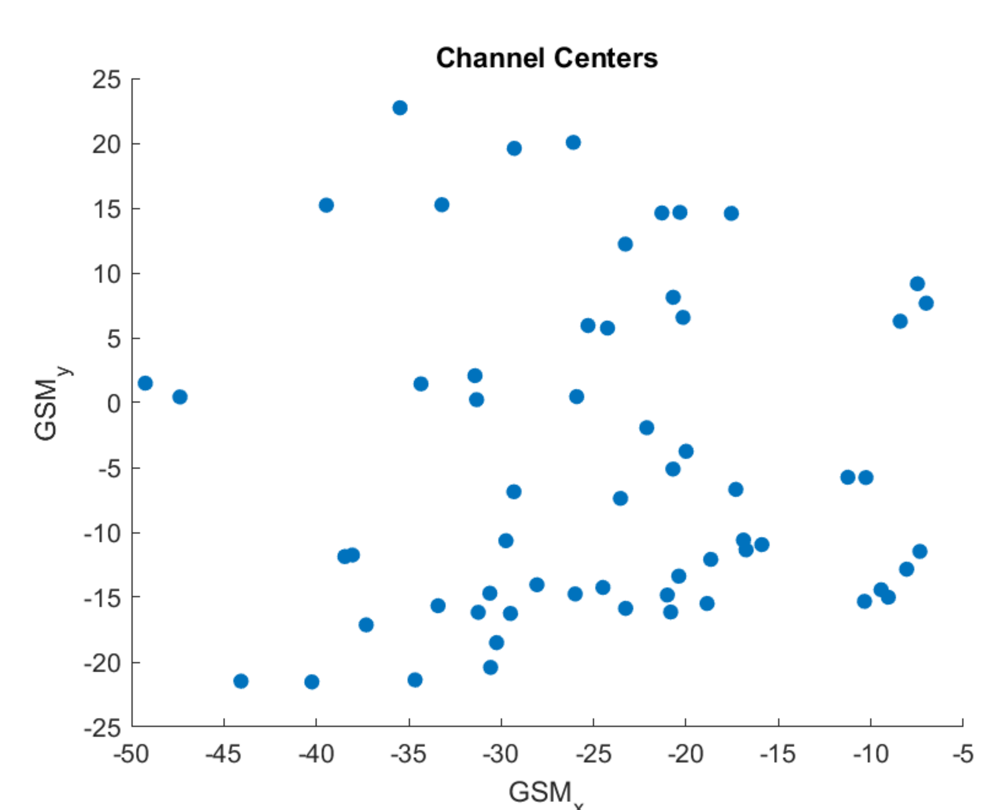
Following the region identification, just the center pixels are marked.



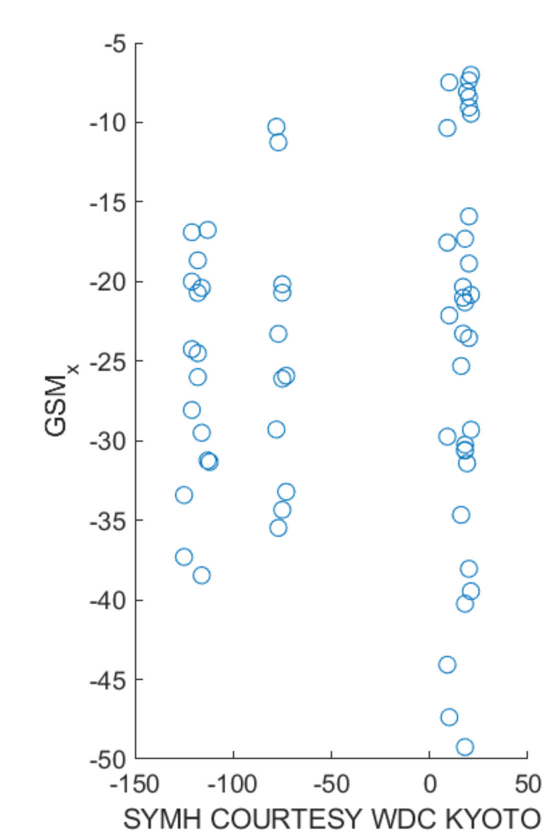
Following the region identification, just the border pixels are marked.

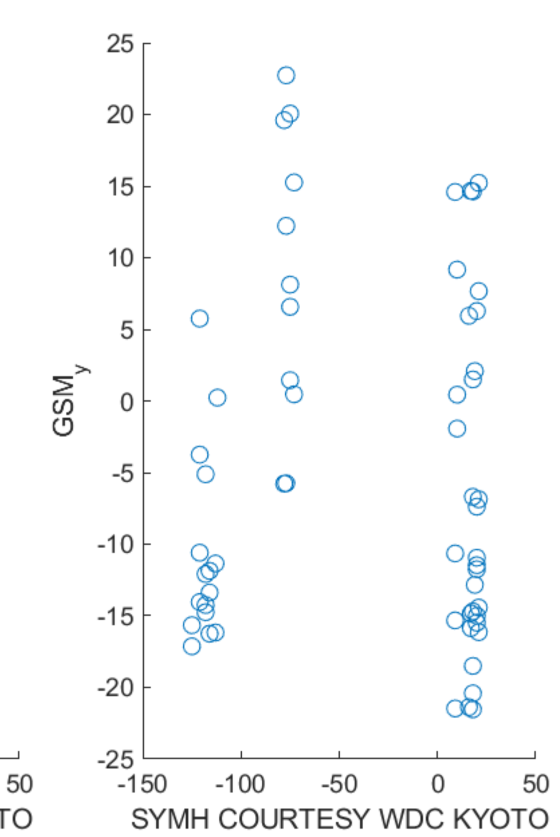
Position of identified regions

The average (mean) *x* and *y* values of each identified region are calculated to identify the "center."



Location of region center along the *x*-axis vs. *y*-axis in GSM coordinates.

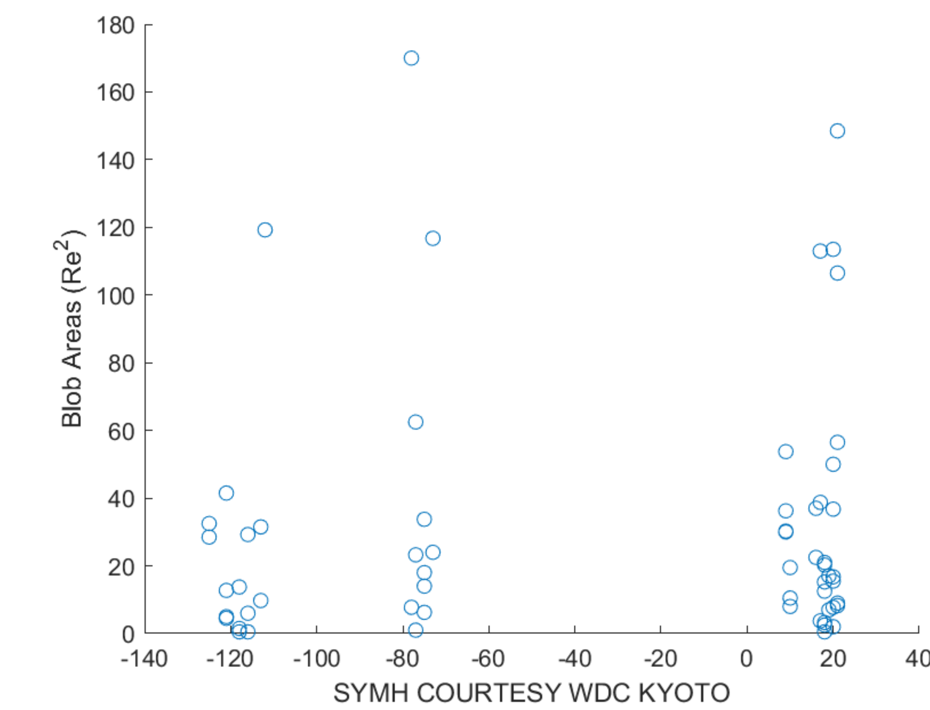


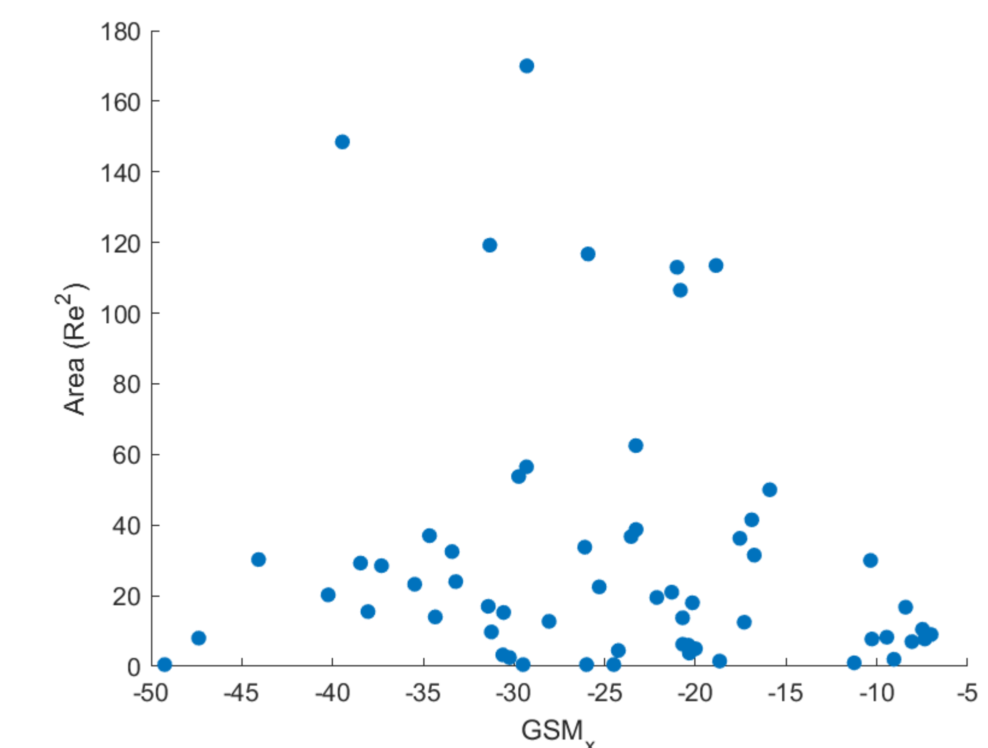


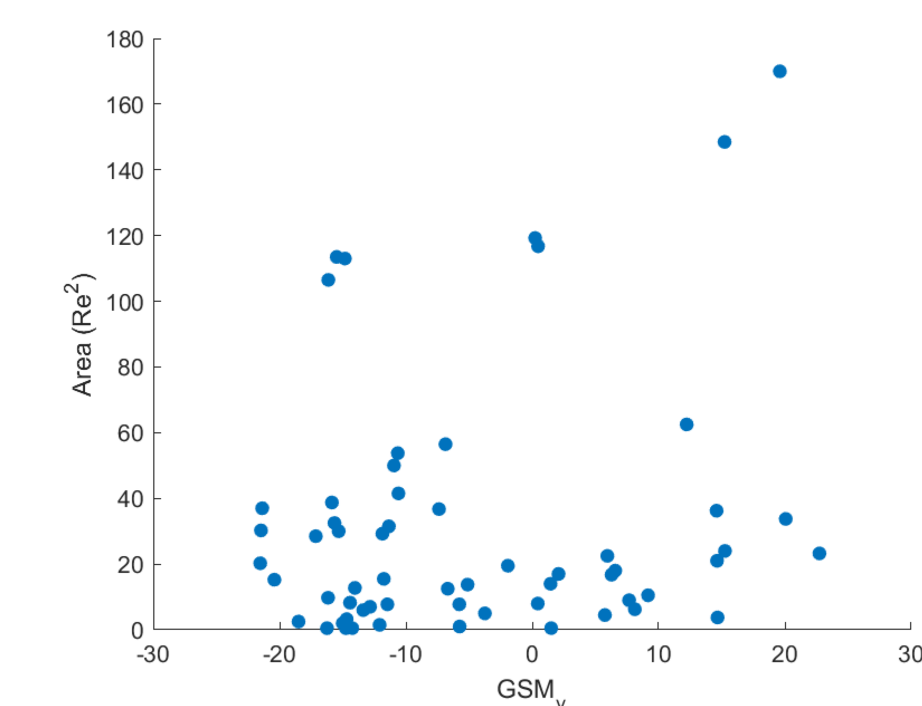
Location of region center along the *x*- (left) and *y*- (right) axis in GSM coordinates as a function of SYM-H index.

Area of identified regions

The area of each region is calculated from the identified pixels. Recall that each pixel is 0.5 × 0.5 R_E. Plots of the area versus SYM-H index, average *x*-axis location and average *y*-axis location are shown below.







Future Work

Identify and analyze intervals with regions of ion temperature enhancement throughout the entire database.

Conduct statistical analysis of characteristics of the identified regions, including size, duration, propagation speed, storm phase, etc.

Acknowledgements

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