DETERMINING THE EQUATORIAL DAYSIDE PLASMA DENSITY USING TRAVEL-TIME MAGNETOSEISMOLOGY

ROBERT RIDGWAY, BRIAN JACKEL   UNIVERSITY OF CALGARY, DEPARTMENT OF PHYSICS AND ASTRONOMY   POSTER NUMBER: SM23B-2486

INTRODUCTION

We have modified an existing method for remotely sensing the magnetospheric plasma density and applied it to the outer dayside magnetosphere. Dynamic pressure changes in the solar wind interact with the magnetosphere and compress it. Once the front reaches the magnetopause, the impulse propagates through the plasma. This wave also enhances the local magnetic field strength.

MODEL OF PROPAGATION

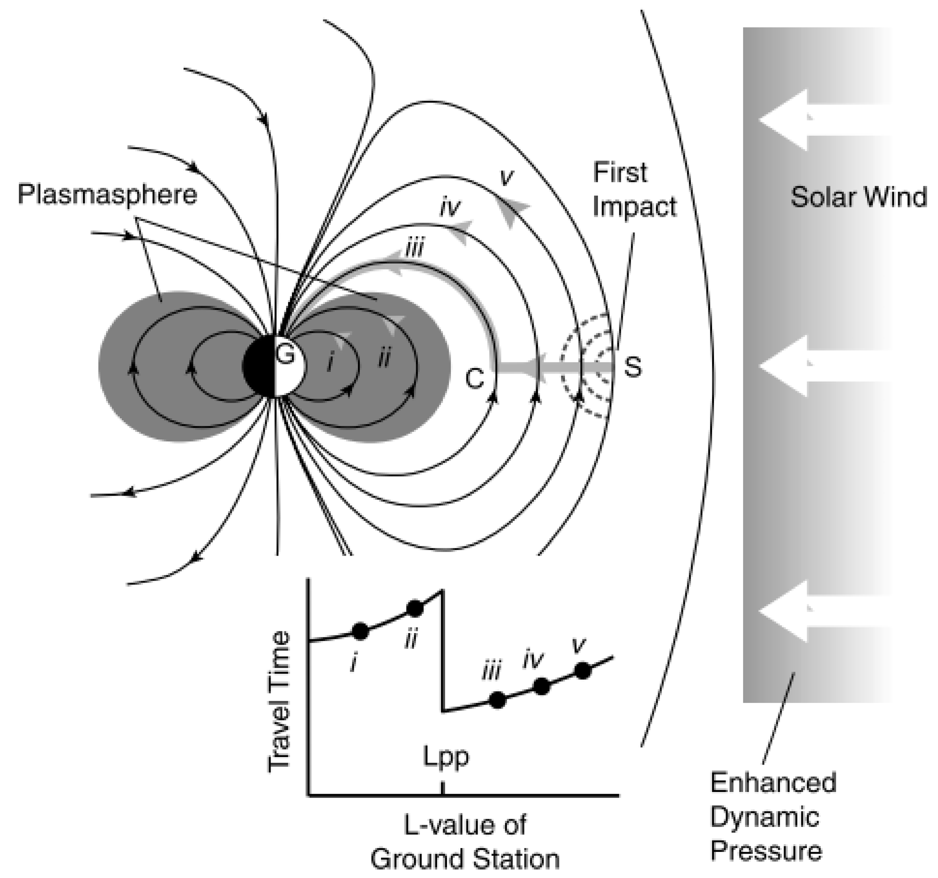

Figure 1: The motion of the impulse can be separated into motion along the equatorial plane and motion along the field lines[5]. Initially I was only interested in propagation along the $\overline{SC}$ line. Using the relation developed by Denton et al. [4], we can include propagation along the field lines as well.
Image Credit: Chi and Russell[2]

METHODS 1

We have adapted travel-time magnetoseismology, originally developed by Chi and Russell[2]. However, we are solely using satellite data for analysis, whereas their method involved ground based sensors. Initially we are restricting ourselves to the dayside magnetosphere. We have represented the travel-time integral as a linear equation.

$$\tau = \int_{r1}^{r2} \frac{1}{v(\vec{r})} ds \approx \sum_n \frac{l_n}{v_n} \tag{1}$$

In the equatorial plane, the impulse propagates at the fast-mode speed

$$v_{ms}^2 = c^2 \frac{v_s^2 + v_A^2}{c^2 + v_A^2} \tag{2}$$

where c is the speed of light, and v_A is the Alfvén speed, defined as

$$v_A = \frac{B}{\sqrt{\mu_o \rho}} \tag{3}$$

OVERVIEW

Pressure fronts in the solar wind induce an impulse in the terrestrial magnetosphere when they impact it. These impulses propagate through the magnetosphere and are recorded by satellites. By measuring the differential travel-times of these impulses from different satellites the density distribution of the plasma can be determined using a tomographic reconstruction process.

I have created a density profile using minute-averaged magnetometer data. This model utilizes a modified form of travel-time magnetoseismology initially developed by Chi and Russell [2]. In time I hope to extend the model using higher resolution datasets allowing the observation of small-timescale processes.

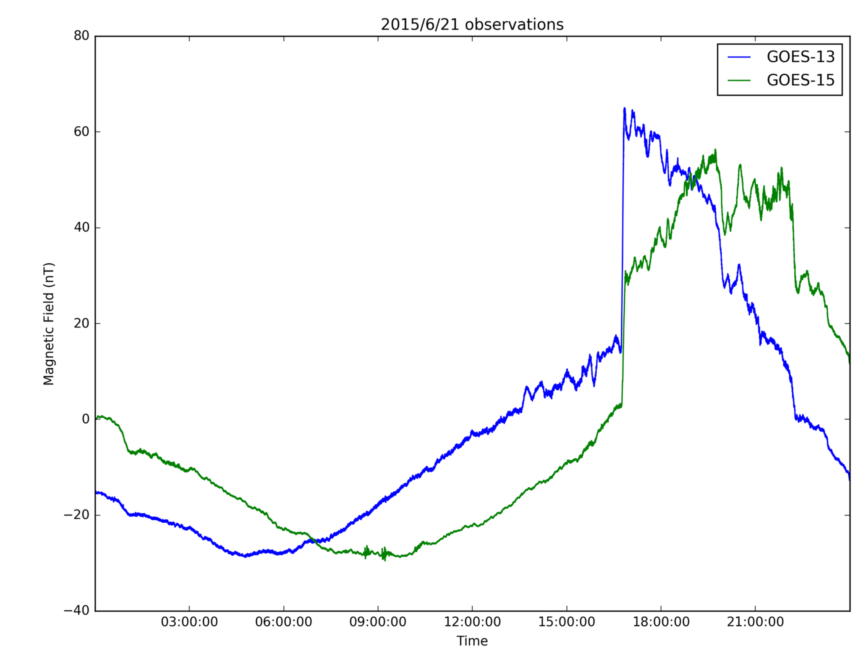

Figure 2: This is an example of an impulse event. At 17:00 we see a fairly rapid increase of 50 nT taking place over 10 minutes in the magnetometer data. Less obvious events occur after the major event.

METHODS 2

An accurate model of the density is determined if we take into account propagation in the equatorial plane as well as propagation along field lines to the satellites. Propagation along the field lines can be included if we assume a model for the density. I am using the field line density model determined by Denton et al. [3][4]

$$n_e = n_{e0}(LR_E/R)^\alpha \tag{4}$$

Where n_{e0} is the equatorial electron density, LR_E is the equatorial radius and α is a parameter affecting the power law, typically 2.5 for the plasmatrough of L=6-8. This allows us to solve for the profile in 3D. If the plasma is assumed to be cold, the ratio between fast-mode and Alfvén speeds is approximately 1. The distance the impulse travels along the field line is folded into the distances traveled in the equatorial plane. Once the density profile is determined, the density along the field lines can be produced.

METHODS 3

The direct travel-times from source to receiver can not be used as we do not know when the impulse leaves the magnetopause. We only know when satellites record the event. However, by using the differential travel-time, the difference in recorded time for two satellites recording the same event, there is a suitable time interval for inversion purposes. Instead of the direct path we are using both paths to either satellite to create a differential length. GOES-13 and GOES-15 are well suited for this purpose. The THEMIS family of satellites could also be used.

There is a substantial archive of publicly available high-quality magnetometer data that we can access. We hope to create density profiles for different solar wind and magnetopause configurations. As well, this data can be correlated with data from the ACE satellite to determine the pressure front orientation. This can be used to estimate the time when the pressure front impacts the magnetosphere, providing a way to remove the differential travel-time which makes the problem more easily determined. This provides us with all the tools we need to create density profiles. As a proof of concept I have used a dataset consisting of average travel-times of events from 1995-2005 in order to produce a baseline density profile.

RESULTS 1

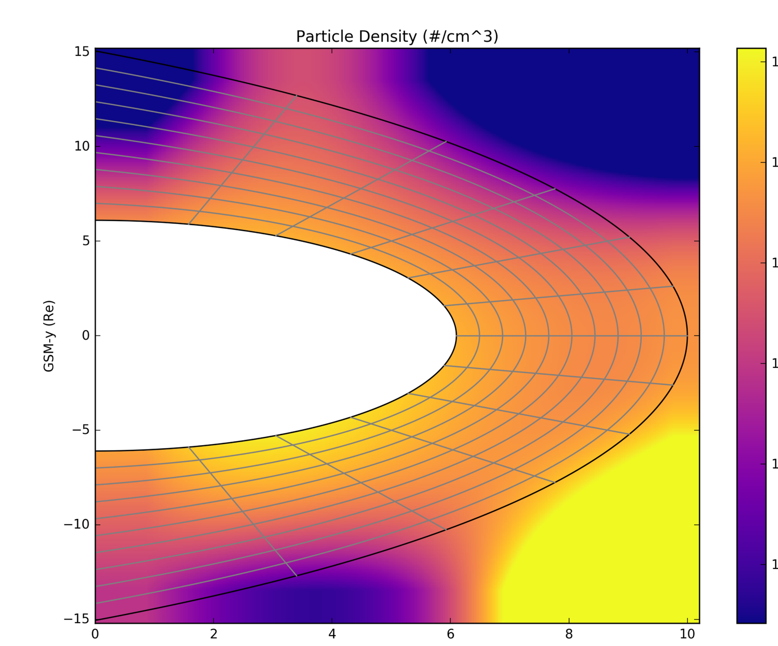

Figure 3: The region was separated into the regions bounded by the gray lines. The values returned for each section is then interpolated. We can see a dusk-dawn asymmetry which seems to agree with previous models [1].

RESULTS 2

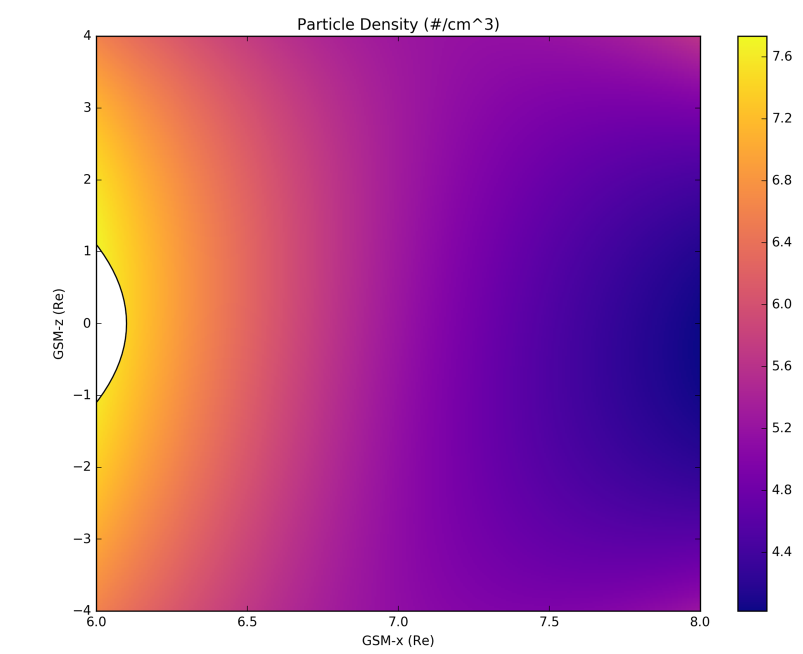

Figure 4: The density along the field lines as retrieved from the averaged dataset. This is the density in the MLT=12 plane.

CONCLUSION

I am creating a method which allows us to observe the density profile of plasma in the outer magnetosphere. Using one minute averaged data we have obtained a density profile covering a wide range of solar wind and local magnetospheric conditions. Future work will include using higher resolution data to obtain more locally accurate density profiles.

REFERENCES

[1] D. L. Carpenter and R. R. Anderson. An ISEE/whistler model of equatorial electron density in the magnetosphere. *J. Geophys. Res.*, 97(A2):1097, 1992.

[2] P. J. Chi and C. T. Russell. Travel-time magnetoseismology: Magnetospheric sounding by timing the tremors in space. *Geophys. Res. Lett.*, 32(18):1–4, 2005.

[3] R. E. Denton, J. Goldstein, J. D. Menietti, and S. L. Young. Magnetospheric electron density model inferred from Polar plasma wave data. *J. Geophys. Res. Sp. Phys.*, 107(A11):1–8, 2002.

[4] R. E. Denton, K. Takahashi, I. A. Galkin, P. A. Nsumei, X. Huang, B. W. Reinisch, R. R. Anderson, M. K. Sleeper, and W. J. Hughes. Distribution of density along magnetospheric field lines. *J. Geophys. Res. Sp. Phys.*, 111(4):1–13, 2006.

[5] Tsutomu Tamao. The structure of three-dimensional hydromagnetic waves in a uniform cold plasma. *J. Geomagn. Geoelectr.*, 16(2):89–114, 1964.

ACKNOWLEDGEMENTS

This work was supported through the Geospace Observatory (GO) Canada initiative of the Canadian Space Agency through grant agreement 14SUGOCGV and the Government of Alberta's Queen Elizabeth II Graduate Scholarship Program.

CONTACT INFORMATION

Robert Ridgway: Email: rjridgwa@ucalgary.ca
Brian Jackel: Email: bjackel@ucalgary.ca