Factors Controlling the Thickness of the Jovian Current Sheet

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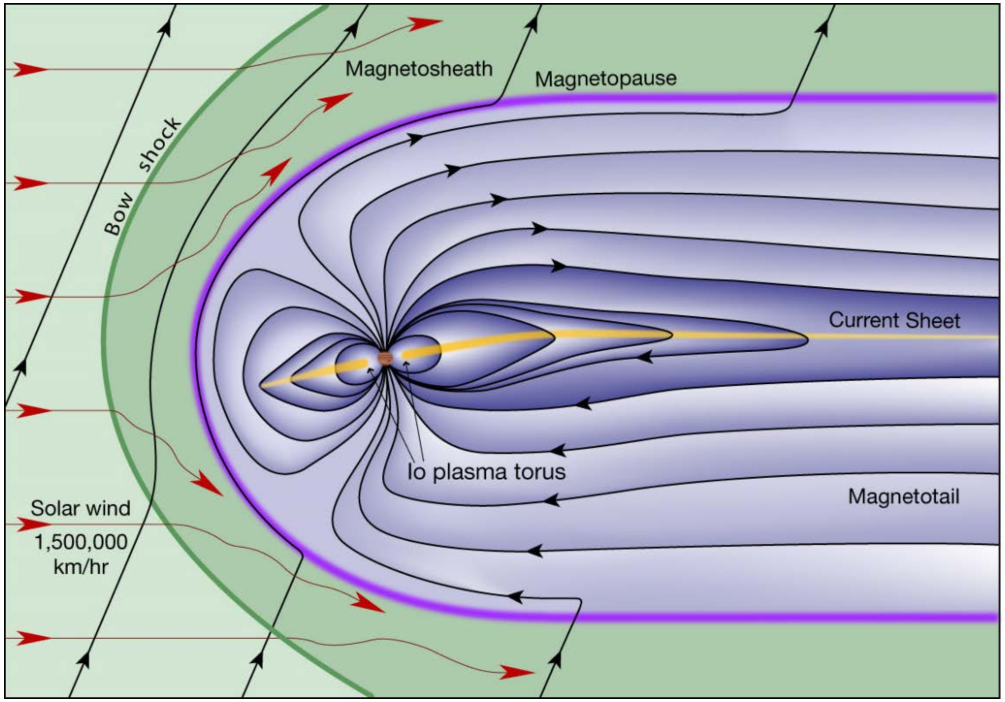
Motivation



The Jovian current sheet located close to the equatorial plane of Jupiter is the main repository of its Iogenic plasma.

However, variations in its thickness and therefore the plasma content of the current sheet with radial distance and local time are hard to get from a single spacecraft measurements.

- Consequently, no systematic studies have been performed so far that characterize the behavior of Jupiter's current sheet thickness in space and time.
- We have developed a new technique to determine the instantaneous motion of Jupiter's current sheet relative to the spacecraft.
- Using this technique, I will show you the first global maps of Jupiter's current sheet in three dimensions.

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Determining Current Sheet Thickness

- Assuming, Harris current sheet geometery, the Current sheet thickness, *D*, can be obtained from the observed radial field profile from:

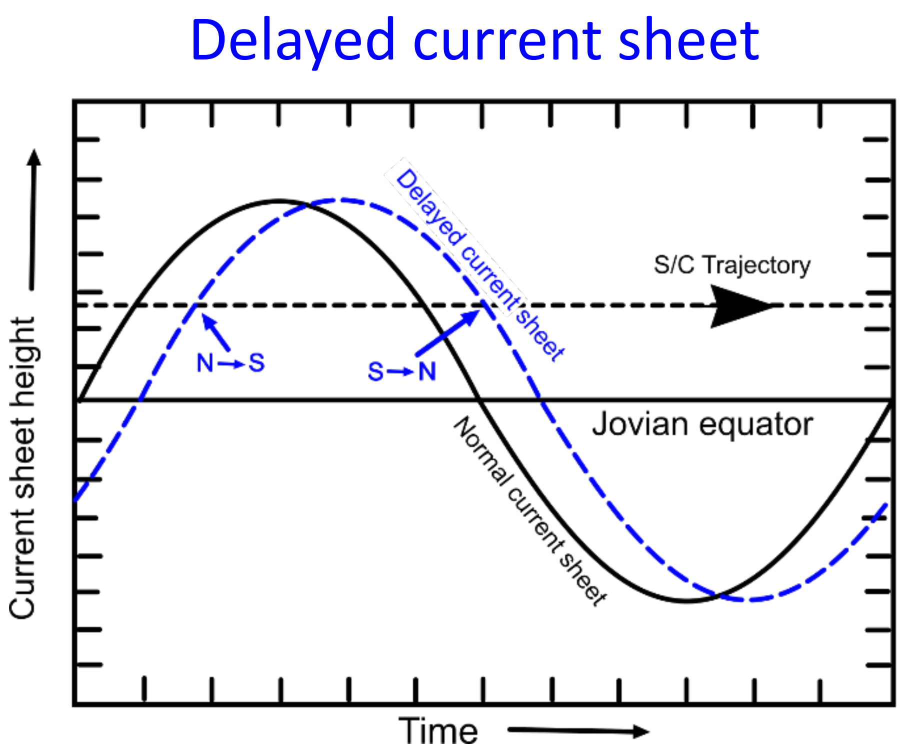
$$B_\rho = B_L \tanh\left(\frac{z - z_{cs}}{D}\right)$$

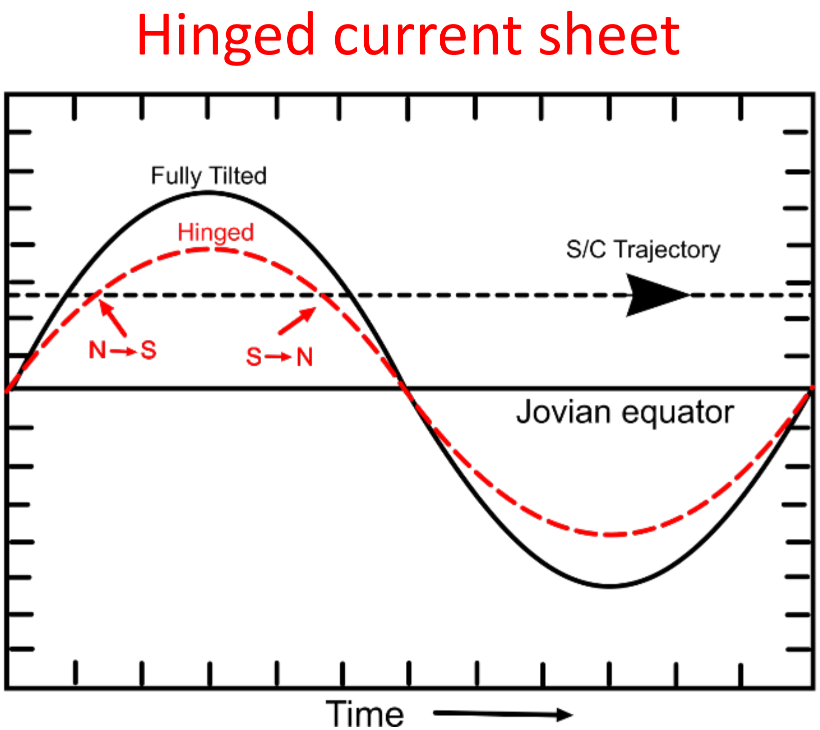
where z is the location of the spacecraft and Z_{cs} is the location of the current sheet obtained from Khurana and Schwarzl, (2005) model.

$$Z_{cs} = \left(\sqrt{\left(x_H \tanh\frac{x_{JSO}}{x_H}\right)^2 + y_{JSO}{}^2}\right)\tan\theta_{VIP4}\cos(\phi - \phi') + x_{JSO}\left(1 - \tanh\left|\frac{x_H}{x_{JSO}}\right|\right)\tan\theta_{sun}$$

where x_{JSO}, and y_{JSO} are the equatorial locations of the observer in JSO coordinates, ϕ is the system III longitude of the s/c, ϕ', is the prime meridian and x_H is the hinging distance beyond which the current is parallel to the average solar wind flow direction .

Local location of the Current Sheet





When a N→S crossing occurs followed by a S→N crossing:

$$\phi_1 - \phi_I' = -(\phi_2 - \phi_I') \Rightarrow \phi_I' = (\phi_1 + \phi_2)/2$$

When a S→N crossing occurs followed by a N→S crossing:

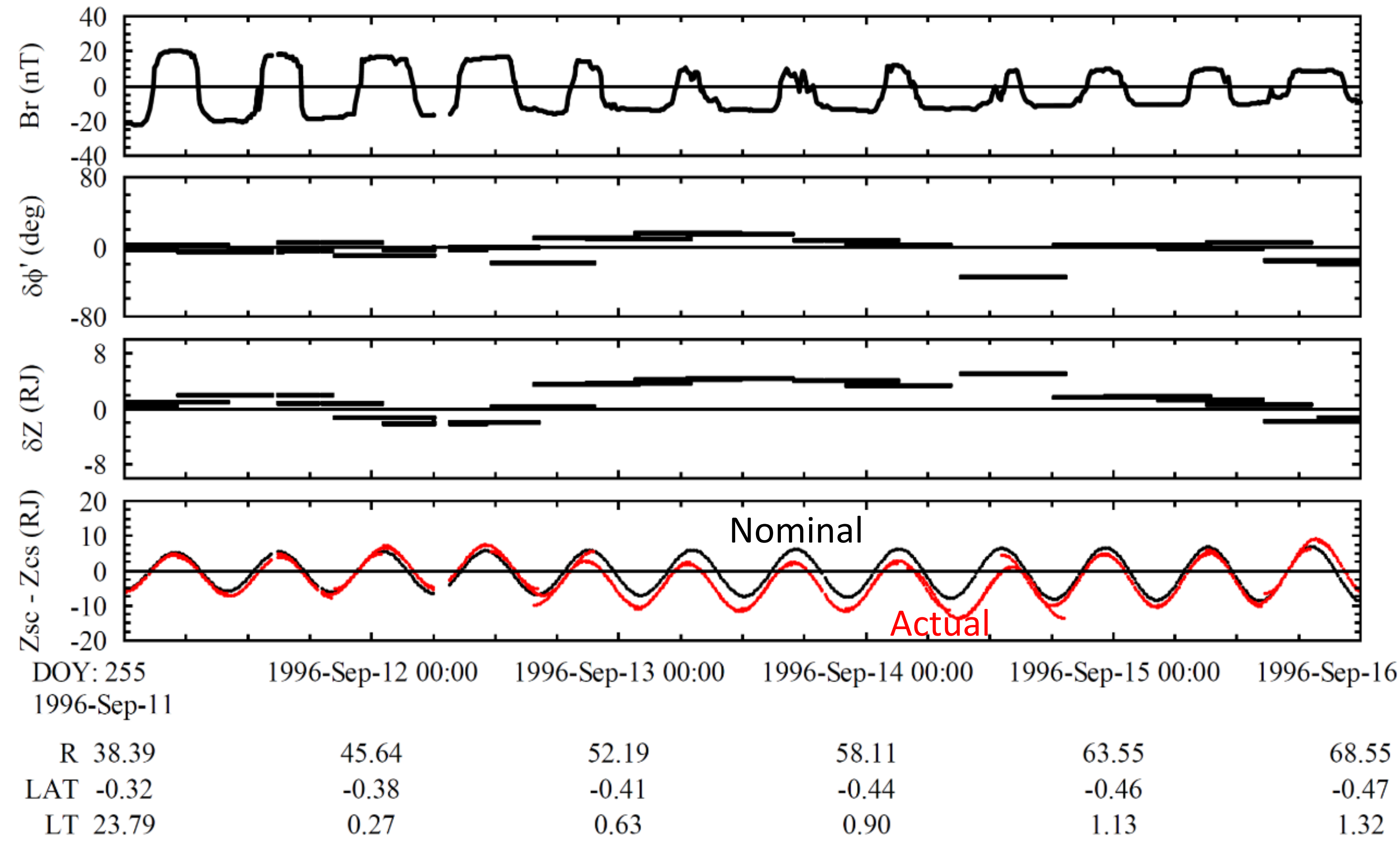
$$-(\phi_1 - \phi_I') = 2\pi + (\phi_2 - \phi_I') \Rightarrow \phi_I' = (\phi_1 + \phi_2)/2 + \pi$$

Calculating instantaneous vertical displacement of the current sheet

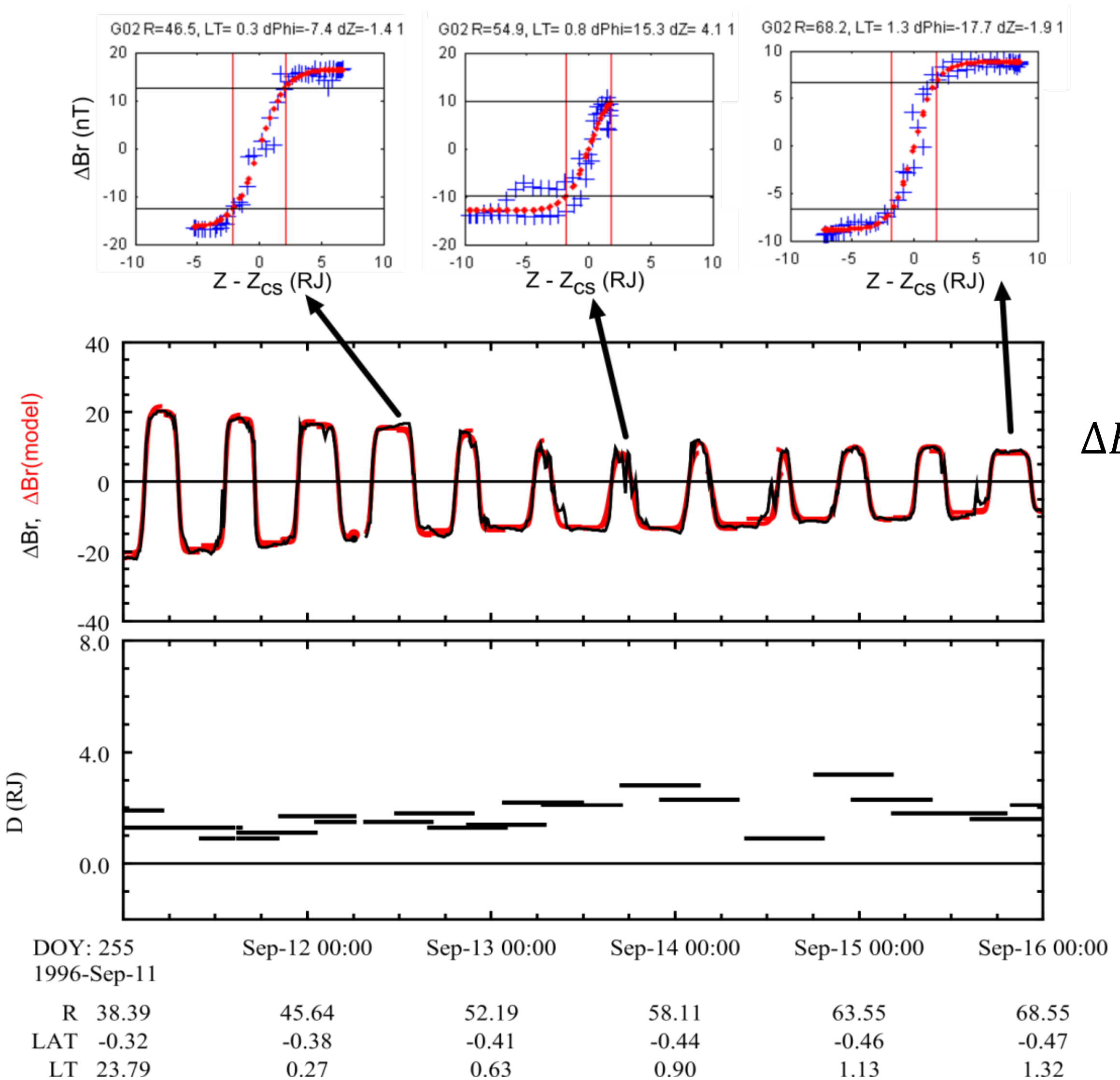
- Once the instantaneous ϕ' has been calculated from the prevous equations, we can calculate the local vertical displacement Δz of the current sheet from the delayed current sheet from:

$$\Delta z = Z_{sc}\Big|_{\text{at crossing}} - Z_{cs}(\text{model}) = Z_{sc}\Big|_{\text{at crossing}} - \left(\sqrt{\left(x_H \tanh\frac{x_{JSO}}{x_H}\right)^2 + y_{JSO}{}^2}\right)\tan\theta_{VIP4}\cos(\phi - \phi_L')$$
$$+ x_{JSO}\left(1 - \tanh\left|\frac{x_H}{x_{JSO}}\right|\right)\tan\theta_{sun}$$

Modeling spacecraft's instantaneous distance from the current sheet.

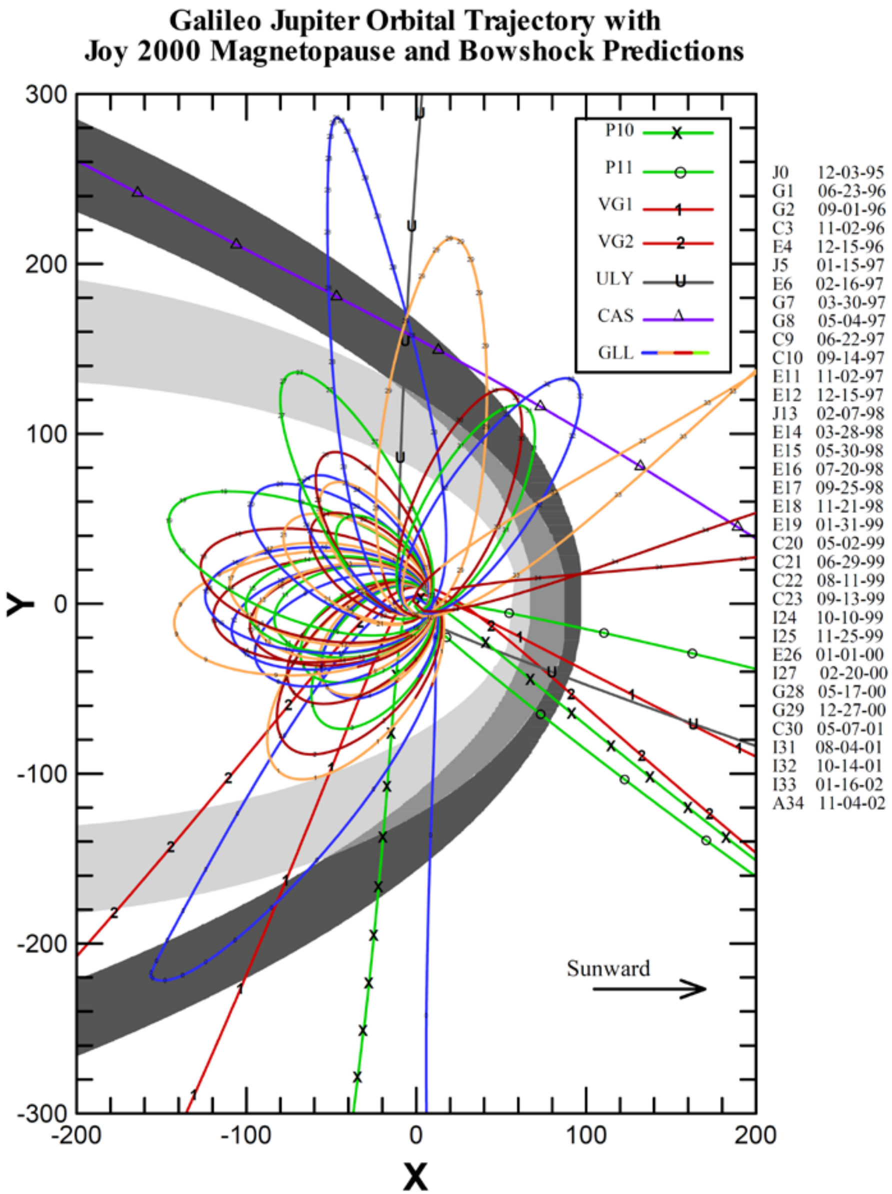


Current sheet thickness from fitting ΔBr to the Harris Current Sheet Equation



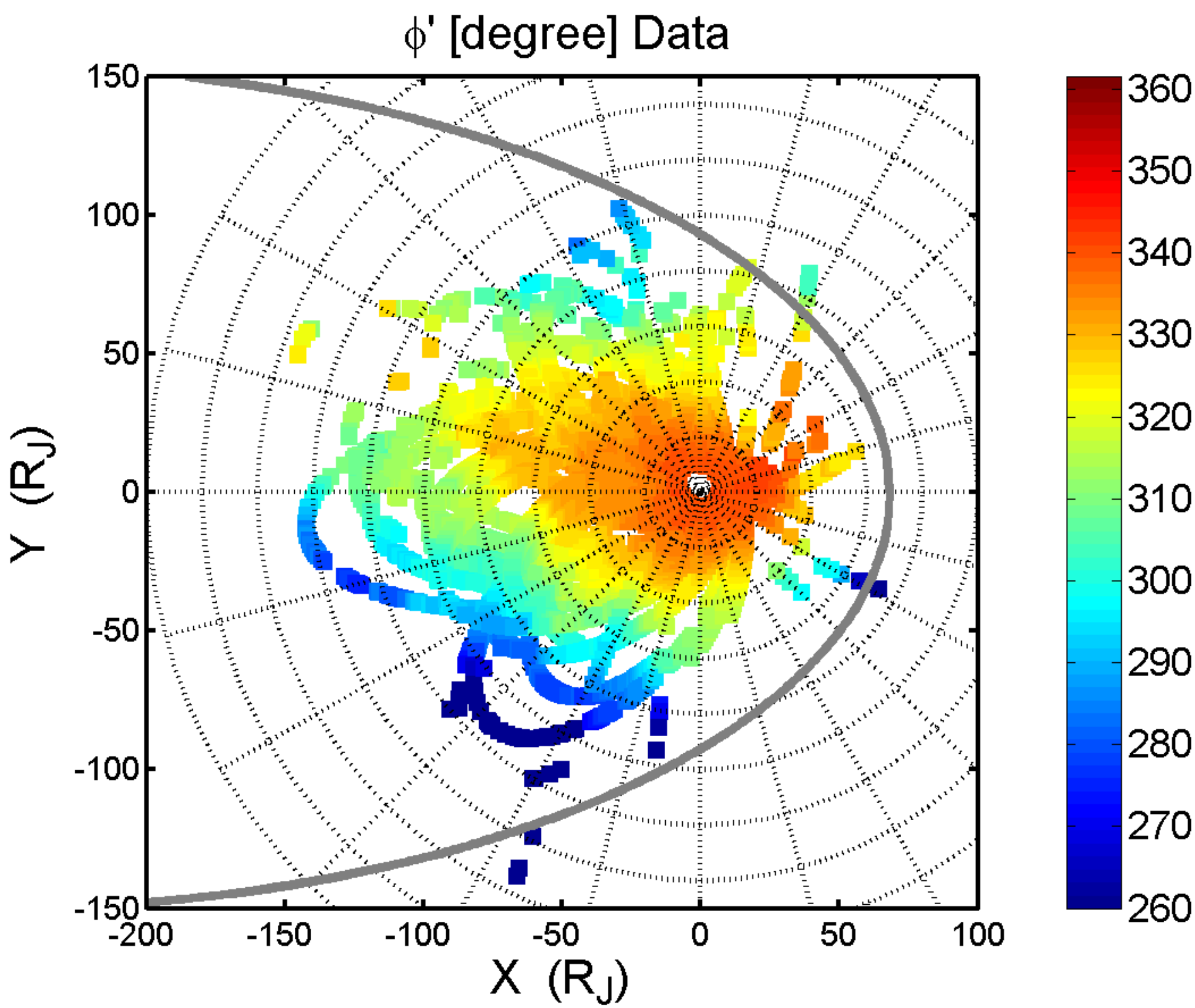
$$\Delta B_r = B_L \tanh\left(\frac{z - z_{cs}}{D}\right)$$

Dataset Used to Infer the Current Sheet Thickness Map

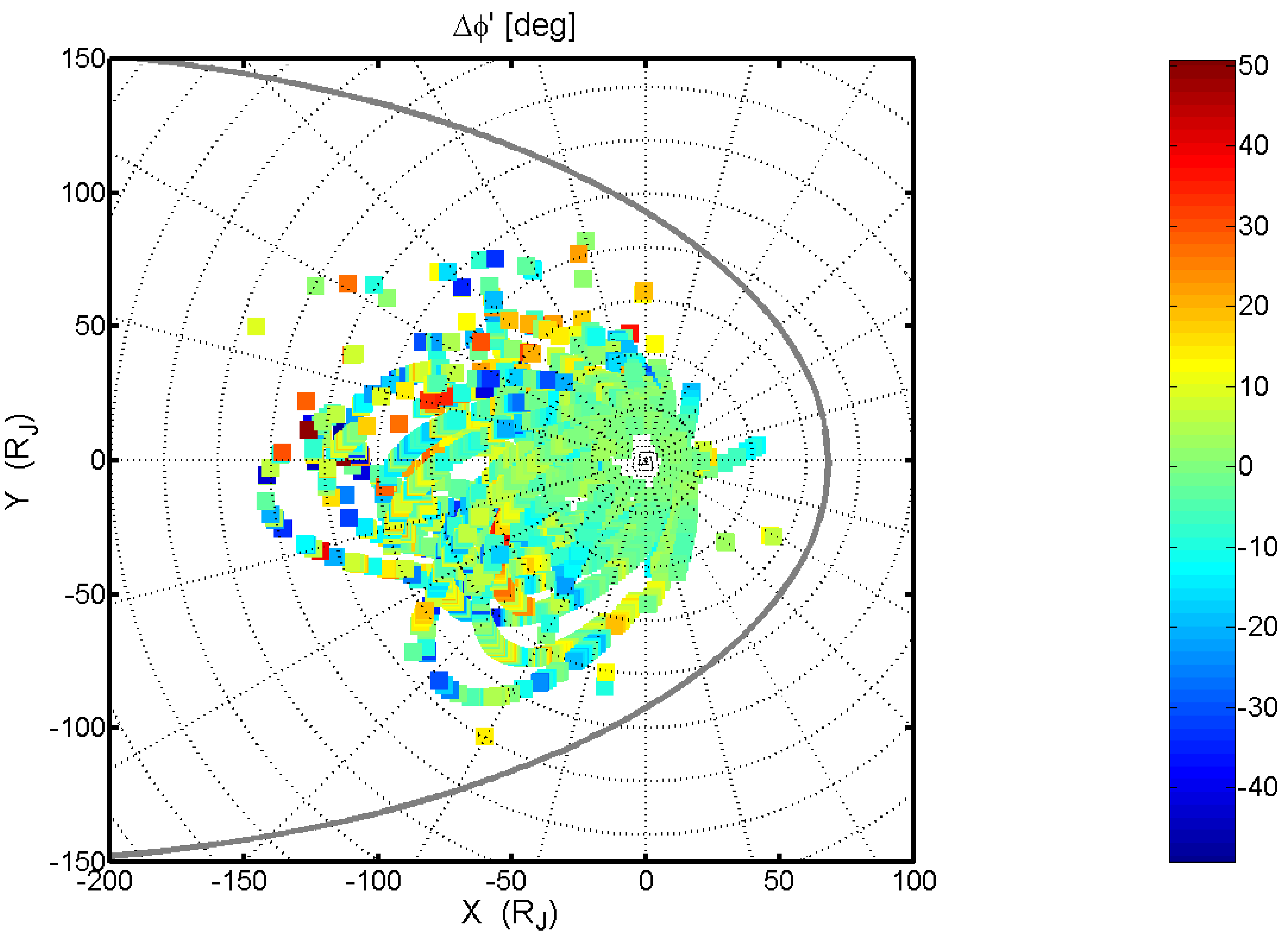


- We use magnetic field data from Pioneers 10 and 11, Voyagers 1 and 2, Ulysses and Galileo spacecraft to determine the thickness of Jovian current sheet in local time and radial distance.
- The available resolutions of data sets are variable and lie between 0.333 s and 32 minutes. The majority of the data were obtained in the real time survey (RTS) mode of Galileo for which the resolution is 24 sec.
- We used 4343 viable pairs of current sheet crossings to obtain our current sheet thickness maps.

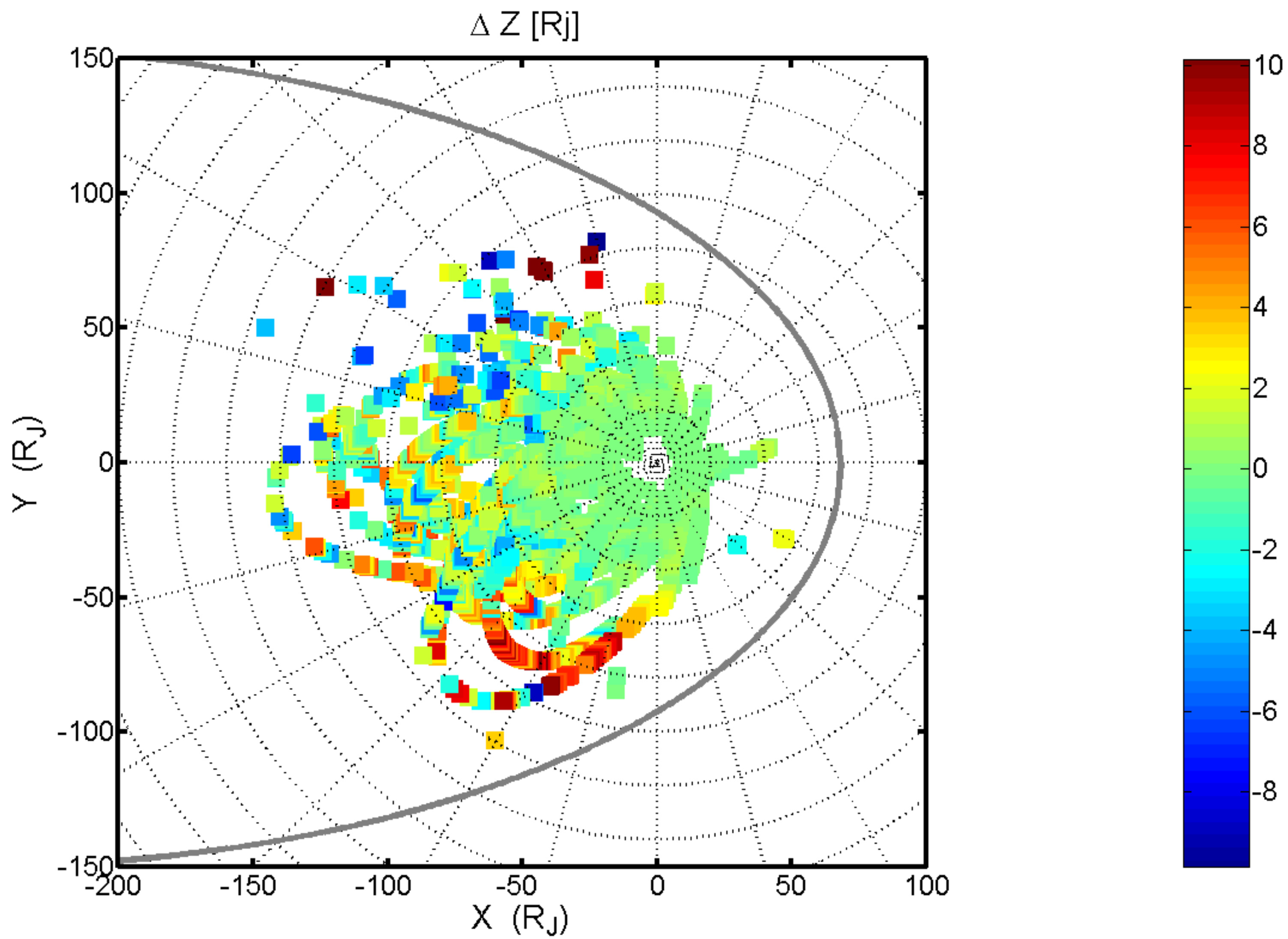
Fitted Prime Meridian



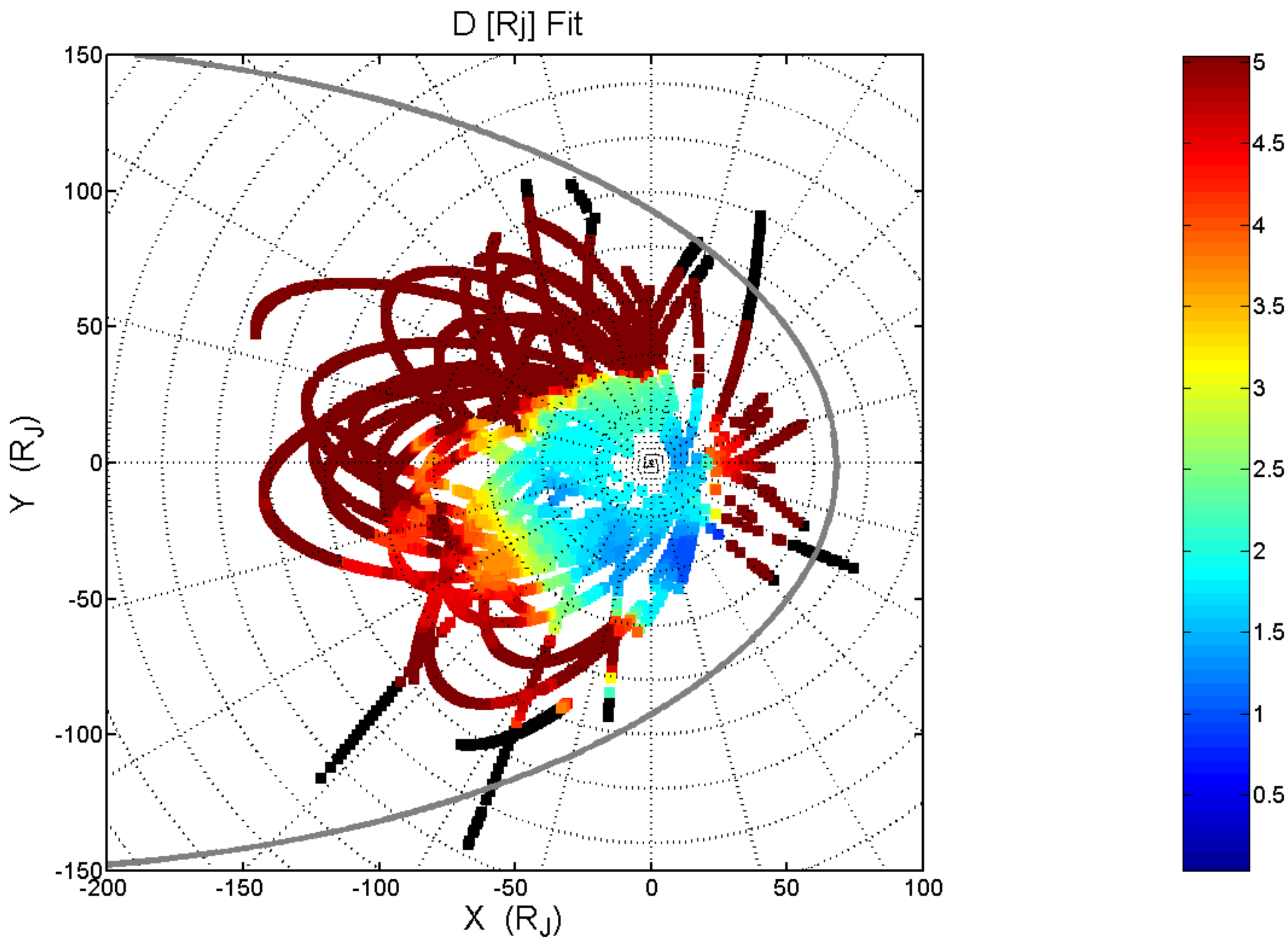
Local Correction to the Current Sheet Prime-Meridian



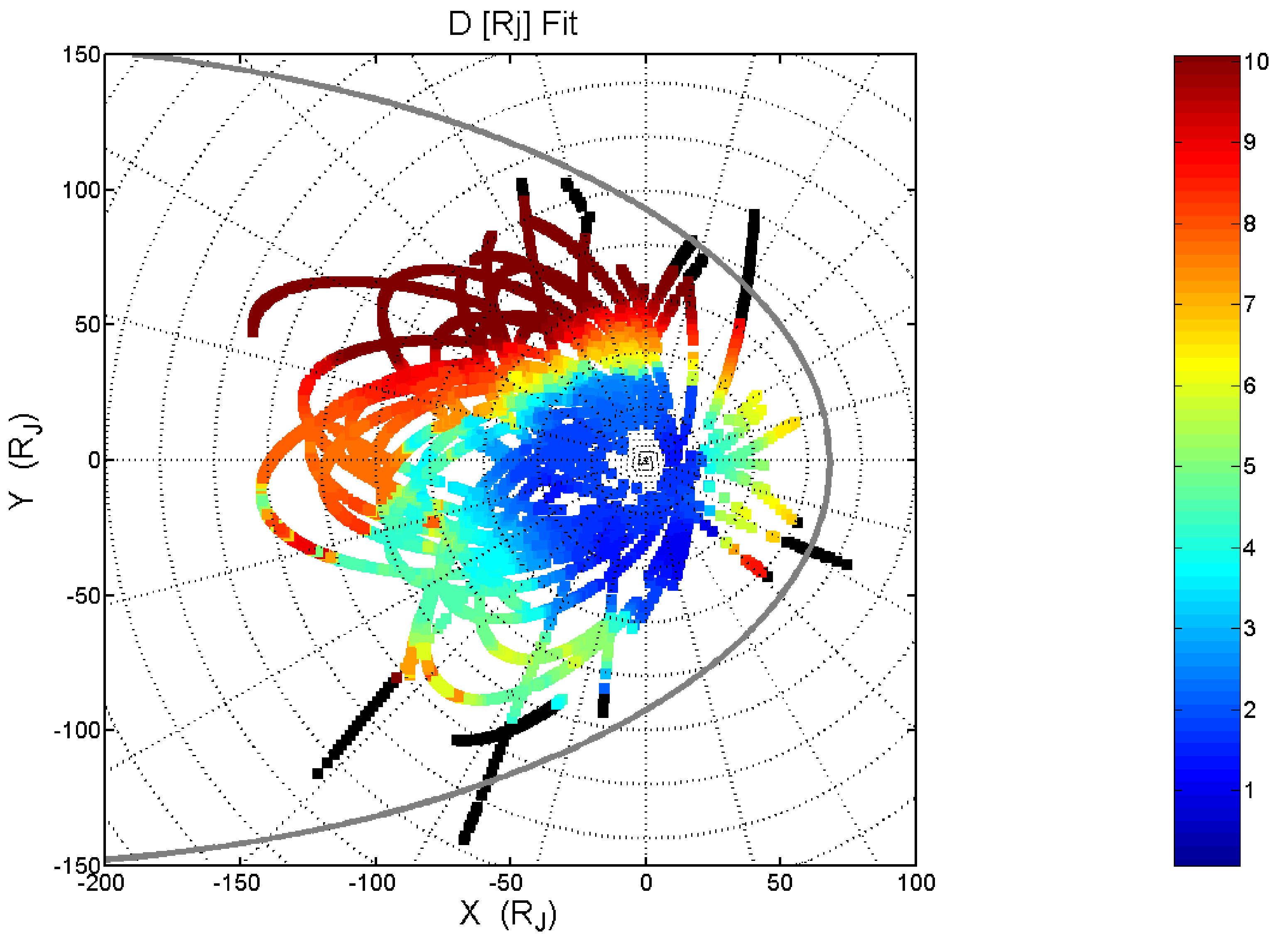
Local vertical displacement of the current sheet



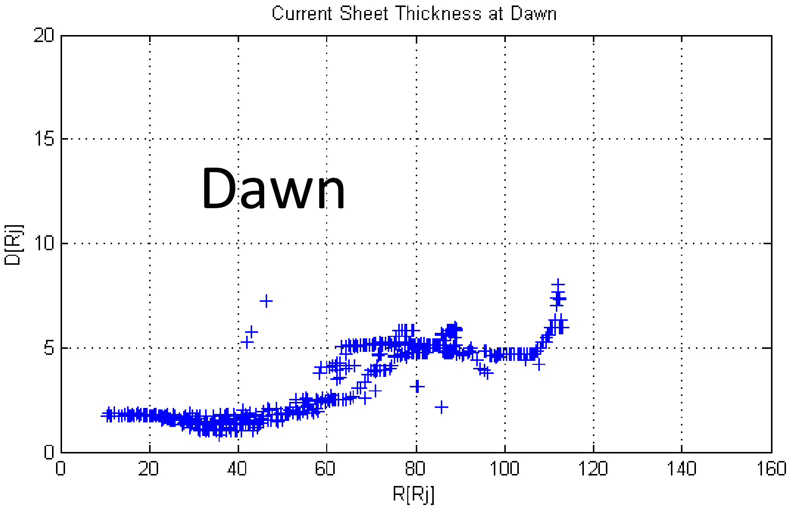
Current Sheet Thickness Map (color Scale Saturated at 5 R_J)

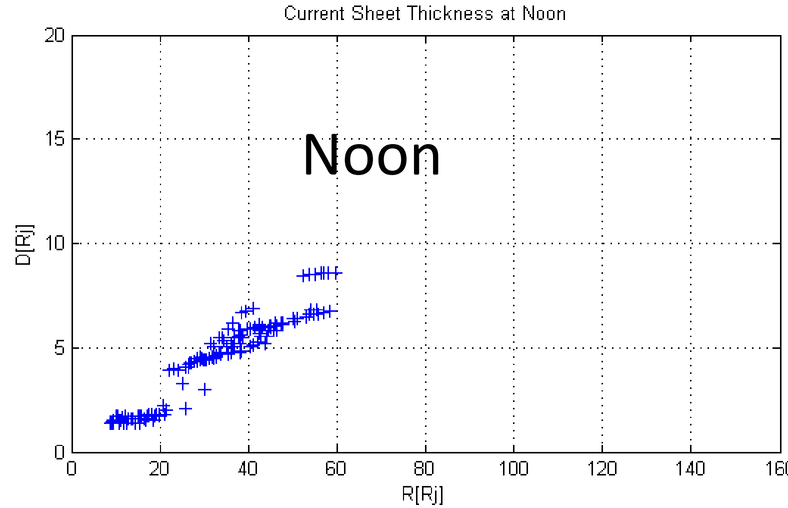


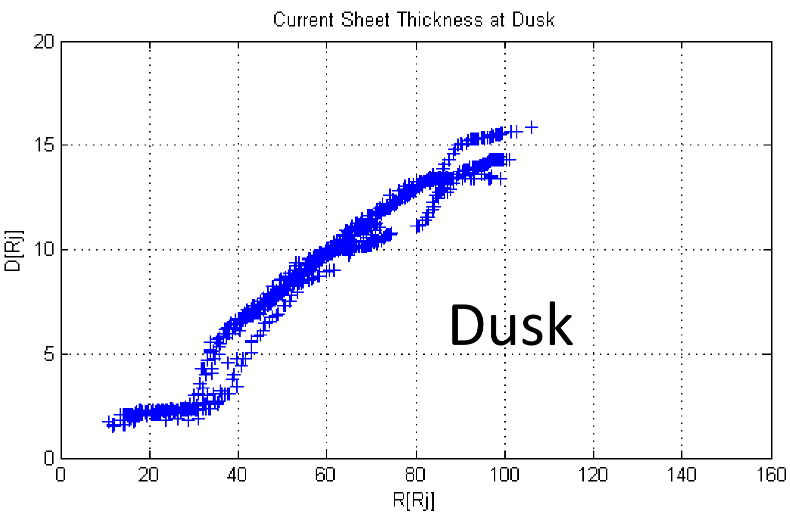
Current Sheet Thickness Map
(color Scale Saturated at 10 R_J)

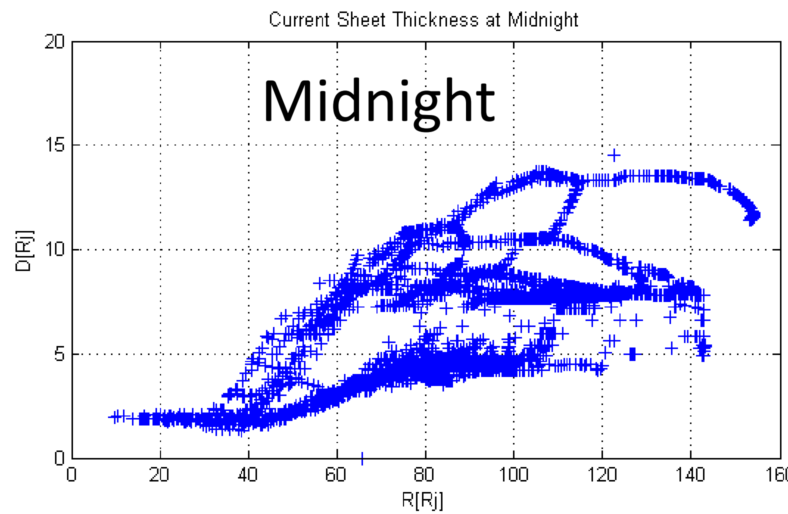


Current Sheet Thickness with Radial Distance









Factors controlling current sheet thickness

Vasyliunas (1983) defined a scale length (h) for the current sheet using:

$$h = \frac{B_\rho(lobe)}{\partial B_\rho/\partial z|_{z=0}} \quad (1)$$

where ρ and z are tangential and normal directions to the current sheet and using stress balance relations in the magnetosphere showed that:

$$\frac{h}{r} \simeq \left|\frac{B_z}{B_\rho(lobe}\right| \frac{2w_{||}^2(1-\chi)}{V_\phi^2+\upsilon w_\perp^2} \quad (2)$$

where r is the radial distance of the measurement, B_z is the normal component of the magnetic field, $w_{||}$ and $w_\perp$ are the thermal speeds of ions in parallel and perpendicular direction to the field, $\chi = \mu_0\rho\left(w_{||}^2 - w_\perp^2\right)/B_z^2$ is the normalized plasma anisotropy and $\upsilon = -\partial \log P_\perp/\partial \log r$ is a measure of perpendicular pressure gradient in the tangential direction.

Equation (2) shows that the current sheet thickness increases where particle pressure gradient is very small such as in the outer magnetosphere.
The current sheet thickness also increases as the ratio of the field at the center of the current sheet (Bz) to that in the lobe increases. This observation explains the observed dawn dusk asymmetry of the current sheet thickness. It is well known that Bz/B(lobe) is stronger in the dusk sector.

Conclusions

- The average half-thickness of the Jovian current sheet in the dawn sector inside of 40 R_J is 1.5 R_J. It then steadily increases to 5 R_J, by a radial distance of 80 R_J.
- The duskside current sheet also has a half-thickness of 1.5 R_J close to Jupiter but it increases to 5 R_J near a radial distance of 40 R_J and further increases to > 15 R_J in the outer magnetosphere.
- The current sheet thicknesses in the dusk and noon meridian are comparable.
- In all local times, the current sheet thickens with radial distance presumably from decreasing plasma pressure gradient in the outer magnetosphere.
- The dawn/dusk asymmetry in thickness arises because the Bz component is much stronger in the dusk hemisphere.