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Cassini observations of ionospheric currents at Titan

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Abstract

We conduct a multi-instrument study in order to infer the currents flowing in the deep ionosphere of Titan. Furthermore, we have used conductivities to estimate the direction and magnitude of the currents and the associated electric fields. We give a first view of how the currents in the ionosphere of Titan are flowing.

1. Introduction

The ionosphere of Titan is created when the atmosphere of the moon becomes ionised. There are several mechanisms that contribute to this, of which photoionisation by EUV from the Sun with associated photoelectron ionisation and particle impact ionisation by electrons and ions from Saturn's co-rotating magnetosphere are often considered the major ones (e.g. Cravens et al., 2005, Wahlund et al., 2005, Ågren et al., 2009). In addition, ion transport from dayside to nightside is believed to play a role in the formation of the ionosphere (Cui et al., 2009). As Titan does not exhibit any large intrinsic magnetic field (Backes et al., 2005), the fact that it is embedded in the magnetosphere of Saturn means that the Saturnian magnetic field drapes around the moon and gives rise to an induced magnetosphere. The configuration of this magnetosphere differs vastly depending on where Titan is located in relation to Saturn. Although, Titan's ionised environment is significantly different from flyby to flyby, a common feature can sometimes be observed. During several deep passes, the magnetic field signature is opposite to the expected configuration of draped field lines.

2. Measurements

2.1 Flyby configuration

Since the initial flyby in October 2004, more than 60 targeted flybys of Titan have taken place. In this paper we focus on T18, T20 and T21. There are mainly two reasons for choosing these flybys. First of all, they all occurred at similar Saturn local time (SLT) 2.28, 2.20 and 2.05 respectively. This means that we can expect the same influence by photoionisation from the sun. Second of all, they showed very similar magnetic conditions between them, before as well as after the flyby of Titan. This is not the general case, even for the flybys occurring at similar SLT, due to the fact that magnetic conditions around Titan change depending on where in Saturn's magnetosphere the moon is located (Bertucci et al., 2007). The magnetic conditions around the moon are not entirely a function of SLT, but also the current solar wind conditions, as well as the period of the co-rotating plasma around Saturn.

2.2 Instrumentation

In this study we combine Langmuir probe (LP), magnetometer (MAG) and electron spectrometer (ELS) measurements in order to map the cold plasma properties, such as magnetic fields and electron number density, below the induced magnetospheric boundary of Titan.

3. Results

The flybys in this study, i.e. T18, T20 and T21, all show a change in magnetic field direction in the deep ionosphere of Titan. Changing to Titan centred spherical coordinates shows that the principal gradient of the magnetic field is in the radial distance which gives rise to currents that locally mainly flow horizontally. By calculating the curl of the magnetic field we infer currents in the deep ionosphere of the moon.

$$\bar{j} = \frac{1}{\mu_0} \nabla \times \bar{B} \qquad (1)$$

As we know the direction of the magnetic field, we can calculate the components of the current that are parallel and perpendicular to the magnetic field.

$$\bar{j}_{\parallel} = \frac{\bar{j} \cdot \bar{B}}{|\bar{B}|} \frac{\bar{B}}{|\bar{B}|} \quad (2)$$

$$\bar{j}_{\perp} = \bar{j} - \bar{j}_{\parallel} \quad (3)$$

Furthermore, we have used conductivities calculated by Rosenqvist et al. (2009), to estimate the parallel, Hall and Pedersen currents, respectively.

$$\bar{j} = \sigma_{\parallel} \bar{E}_{\parallel} + \sigma_H \hat{b} \times \bar{E}_{\perp} + \sigma_P \bar{E}_{\perp} \quad (4)$$

In addition, we have also made first estimates of the electric fields in the examined regions.

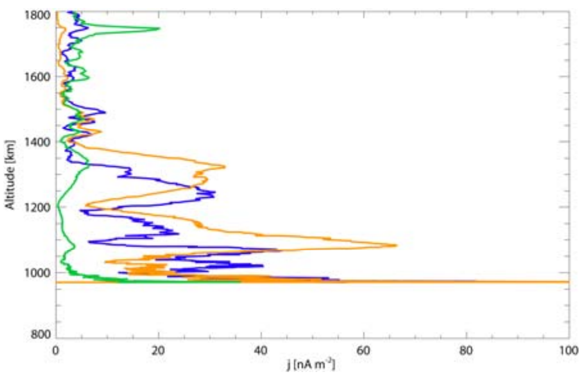

Fig 1. The calculated currents for the inbound leg of flyby T18. The parallel current is shown in blue, the Pedersen current in green and the Hall current in orange. The peak in magnitude at the bottom of the plot at ≈ 950 km is not real, but due to the fact that *dr* goes to zero.

4. Summary and Conclusions

In this paper we have shown that there are currents flowing on the order of 10 – 70 nA/m^2 in the deep ionosphere of Titan. Below approximately 1400 km the currents are principally parallel and Hall, i.e. flowing parallel to the magnetic field and perpendicular to both the magnetic field and the electric field, respectively. At higher altitudes the Pedersen current seemingly becomes more prominent, which might be due to current sheets. We believe the currents are due to electric fields set up by the dynamic magnetospheric environment of Titan. In addition, it is possible that the altitude structures seen in the data are due to Alfvén waves impacting Titan and generating currents.

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