EPSC Abstracts
Vol. 6, EPSC-DPS2011-1532-2, 2011
EPSC-DPS Joint Meeting 2011

Localized Magnetospheric Heating of Titan's Thermosphere

D. Snowden (1), R. V. Yelle (1), J. Cui (2), M. Galand (3), T. T. Koskinen (1), P. P. Lavvas (1), and I.C.F. Müller-Wodarg (3)
(1) Lunar and Planetary Laboratory, Tucson, AZ, USA, (2) National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China, (3) Department of Physics, Imperial College, London, U.K., (dsnowden@lpl.arizona.edu)

Abstract

The vertical density profile of N_2 and CH_4 measured by Cassini's Ion Neutral Mass Spectrometer (INMS) indicates that the temperature of Titan's thermosphere is highly variable both spatially and temporally. Features that appear to be caused by strong localized heat sources ($\sim 10^{-9}$ to 10^{-10} ergs cm^{-3} s^{-1}) are frequently observed. We examine magnetospheric electron precipitation and frictional heating in discrete current layers to determine if the interaction between Titan's upper atmosphere and Saturn's magnetosphere is the source of localized heating. We also examine the time-scales of the observed localized heating to determine if prior configurations of Titan's induced magnetosphere are 'fossilized' in Titan's neutral atmosphere.

1. Introduction

Cassini Ion Neutral Mass spectrometer indicates that the thermal structure of Titan's upper atmosphere is as varied and complicated as Titan's magnetospheric interaction. The variation in thermal structure is not well organized with solar zenith angle, indicating another significant energy source is needed. Two candidates that warrant further investigation are heating by gravity tidal waves as described by Strobel [2006] and heating due to the interaction between Titan's upper atmosphere and electromagnetic fields and particles from Saturn's magnetosphere. Global multi-fluid models of Titan's plasma interaction will be used to evaluate Titan's magnetospheric interaction and assess if it is the source of discrete structures detected in Titan's thermosphere by Cassini INMS.

2. Electron Precipitation

Previous estimates of heating by suprathermal electrons (e.g. [4]) have not accounted for the full energy spectrum of electrons observed near Titan by Cassini's Electron Spectrometer (CAPS-ELS) and Low Energy Magnetospheric Measurement system (LEMMS) [6]. Furthermore, the complex three-dimensional and time-varying aspects of magnetospheric electron precipitation has not been fully addressed. The trajectory and energy deposition of precipitating electrons are determined by the orientation of draped magnetic fields in Titan's ionosphere. The magnetic field configuration is complicated because Saturn's magnetic field orientation near Titan frequently changes and the lifetime of magnetic field lines within Titan's ionosphere is estimated to be several hours [3].

To quantify heating due to magnetospheric electrons in Titan's thermosphere we use a three-dimensional model of Titan's plasma interaction to determine the magnetic field topology through Titan's ionosphere for several configurations. Next a multi-stream model is used to determine neutral heating rates due to magnetospheric electrons along simulated field lines.

3. Frictional Heating

Recently, Ågren et al. [2011] reported observations of discrete current layers and horizontal electric fields in Titan's upper atmosphere. The magnitude of the observed electric field was 0.5 to 3 μVm^{-1}, implying plasma drifts speeds on the order of several hundred meters per second. Localized frictional heating and momentum exchange due to ionospheric currents may effect the structure of Titan's thermosphere. We find that the heating rate due to the ionospheric currents reported in Ågren et al. [2011] is on the order of 10^{-11} ergs cm^{-3} s^{-1}. A 3D multi-fluid model of Titan's plasma interaction that simulates current layers and plasma drifts in Titan's ionosphere in agreement with the results of Ågren et al. [2011] is used to investigate how current layers might heat Titan's neutral atmosphere.

4. Timescales

Titan's plasma environment changes on timescales ranging from tens of minutes to several hours, depending on Titan's location with Saturn's magnetosphere ([7]). Bell et. al. [2011] recently studied the time-dependent response of Titan's upper atmosphere to heating from ion precipitation over half a Titan day and found that heating and cooling time-scales due to episodic heating rates of $\sim 10^{-11}$ ergs cm^{-3} s^{-1} were about half a Titan day, depending on altitude. Similarly, we examine the thermal response to localized heat sources to determine how INMS observations are affected by 'fossilized' heating events from prior configurations of Titan's induced magnetosphere.

5. Summary and Conclusions

The thermal structure of Titan's upper atmosphere is highly variable both spatially and temporally. The observed variable thermal structure indicates that strong localized heat sources are needed to produce the neutral density structure observed by Cassini's INMS. We examine electron precipitation and frictional plasma heating to determine if Titan's interaction with Saturn's magnetosphere is the source of localized heating in Titan's thermosphere. We also examine the timescales of localized heating events to better understand how to relate the structure of Titan's upper atmosphere to the current and prior configurations of Titan's induced magnetosphere.

References

[1] Ågren, K., et al. (2011), Detection of currents and associated electric fields in Titan's ionosphere from Cassini data, J. Geophys. Res., 116, A04313, doi:10.1029/2010JA016100.

[2] Bell, J. M., J. Westlake, and J. H. Waite Jr. (2011), Simulating the time-dependent response of Titan's upper atmosphere to periods of magnetospheric forcing, Geophys. Res. Lett., 38, L06202, doi:10.1029/2010GL046420.

[3] Bertucci, C., et al. (2008), The Magnetic Memory of Titan's Ionized Atmosphere, Science, 321(5895), 1475-1478, doi:10.1126/science.1159780.

[4] De La Haye, V., J. H. Waite Jr., T. E. Cravens, S. W. Bougher, I. P. Robertson, and J. M. Bell (2008), Heating Titan's upper atmosphere, J. Geophys. Res., 113, A11314, doi:10.1029/2008JA013078.

[5] Rymer, A. M., H. T. Smith, A. Wellbrock, A. J. Coates, and D. T. Young (2009), Discrete classification and electron energy spectra of Titan's varied magnetospheric environment, Geophys. Res. Lett., 36, L15109, doi:10.1029/2009GL039427.

[6] Simon, S., et al. (2011), A systematic survey of Cassini magnetometer observations from flybys TA–T62, Planetary and Space Science, Volume 58, Issue 10, Pages 1230-1251.

[7] Strobel, D. (2006), Gravitational tidal waves in Titan's upper atmosphere, Icarus, Volume 182, Issue 1, Pages 251-258.