Annual Variation of the Plasmasphere Mass Density at L = 1.6 - 1.8 as deduced from Geomagnetic Field Line Resonance Measurements

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Introduction

The annual variation is one of the more characteristic temporal variations in plasmaspheric density and so far has been studied mostly using whistler measurements [*Lemaire and Gringauz*, 1998, and references therein]. Continuous ground-based monitoring of the plasmaspheric density can be also done by measuring the geomagnetic field line resonance (FLR) period T_R at a given *L*-shell, since T_R is $\propto \rho_{eq}^{1/2}$ (ρ_{eq} being the equatorial plasma mass density).

In the present work we investigated the annual variation of ρ_{eq} using T_R measurements at two different magnetic shells (*L* = 1.61, 1.83) obtained by applying the cross-phase technique to the ULF magnetic signals recorded at the South European Geomagnetic Array (SEGMA, ~ 15°E) during 2001-2008.

Observations

Figure 1 shows the daily means of the resonance period T_R. Red horizontal lines indicate the yearly medians. The bottom panel show the corresponding behaviour of the proxy for the solar EUV: $P_{10.7} = (F_{10.7} + \langle F_{10.7}\rangle) / 2$, where $\langle F_{10.7}\rangle$ is the three solar rotation average of $F_{10.7}$.

A general trend of decresing period with decreasing solar index [*Vellante et al.*, 2007] is clearly visible. Some evidence of an annual variation with minimum values in the central part of the year can be also seen at *L* = 1.61 in 2002, 2003 and 2006.

Daily means (0900 – 1600 LT)

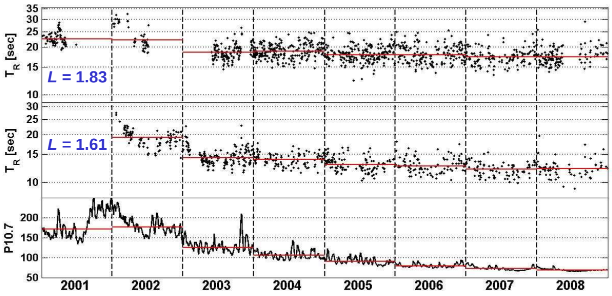

Figure 1

Statistical analysis

In order to separate the effects of solar activity and seasonal dependence we fitted the observations with the following analytical model:

$$\log T = \log T_o + b\,(P_{10.7} - 130) + A_1 \cos[\omega_1(d - d_1)] + A_2 \cos[\omega_2(d - d_2)]$$

where:

d is the day number (DoY) ; $\omega_1 = 2\pi / 365$ day^{-1} ; $\omega_2 = 2\omega_1$; the phases d_1 and d_2 of the annual and semiannual modulation correspond to the days when the modulation reaches the maximum.

With this formulation, the annual and semiannual variations are expressed as factors modulating the resonance period. A similar expression was adopted by *Carpenter and Anderson* [1992] for constructing an empirical model of the equatorial electron density in the plasmasphere.

The parameters of the least squares fit to the daily values of Figure 1 are reported in **Table 1**. Using the b parameter in Table 1, all daily values have been reduced to $P_{10.7} = 130$ and monthly medians of these reduced values have been determined (**Figure 2**). The annual variation now stands out more clearly and some signature appears also at *L*=1.83 (in 2002, 2003, 2004, 2006).

Monthly medians (reduced to $P_{10.7}$ = 130)

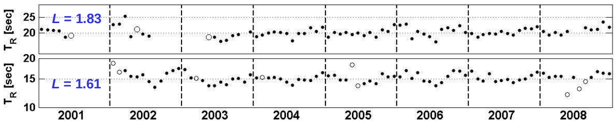

Figure 2

Table 1. Results of the best fit

L	# points	cor.coef	$T_o(s)$	*b*	10^{A_1}	d_1	10^{A_2}	d_2
1.83	1098	0.62	20.3	0.0012	1.042	Dec. 23	1.024	Apr. 27
1.61	716	0.85	15.2	0.0018	1.059	Jan. 6	1.002	Mar. 6

The temporal pattern of the annual and semiannual components determined by the best fit is shown in **Figure 3**. The main features are the following:

***L*=1.83:** the annual component modulates T_R by ± 4% with extreme values at solstices; the semi-annual component is smaller (modulation ±2%), maximum values in late April and late October; the resulting variation (annual + semiannual) is maximum in November with values 12% higher than in July.

***L*=1.61**: only the annual component is significant, maximum in early January with values 12% higher than in June/July.

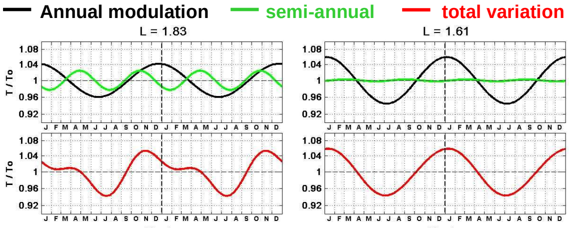

Figure 3

Theoretical modelling

We use a physical numerical model of the plasmasphere-ionosphere system [*Förster and Jakowski*, 1988]. Two different simulated conditions are considered:

high solar activity ($F_{10.7} = \langle F_{10.7}\rangle = 180$) and low solar activity ($F_{10.7} = \langle F_{10.7}\rangle = 80$).

Monthly values of the predicted FLR periods (noon time) at both L-shells are computed and a decomposition in terms of annual and semiannual modulations has been carried out. The resulting annual variation is displayed in **Figure 4** in the same format as in Figure 3.

A good agreement (both in amplitude and phase) is observed between the simulated high solar activity conditions (red line) and the experimental observations. In particular, the model predictions confirm a minor contribution of the semiannual variation at *L*=1.61, and the presence of a secondary maximum in March/April at *L*=1.83.

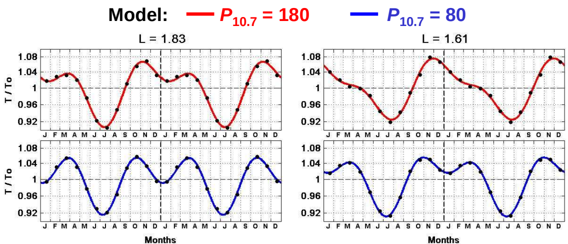

Figure 4

Conclusions

After converting T_R values into equatorial plasma mass densities ($\rho_{eq} \propto T_R^2$), we deduce density values at *L* = 1.61 to be ~ 25% larger in December/January with respect to June/July.

A similar excursion is inferred at *L*=1.83 although (because of a significant contribution of the semiannual variation) the maximum value occurs in November.

Good agreement is observed with predictions given by a physical-numerical model of the plasmasphere.

We then confirm previous results obtained from whistler [*Lemaire and Gringauz*, 1998] and satellite [*Clilverd et al.*, 2007] measurements showing that the annual variation in the European longitudinal sector is of much lower amplitude than that in the American sector essentially because of a smaller asymmetry in the ionospheric solar illumination at opposite ends of the magnetic field lines.

Acknowledgments

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