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Analysis of the August 14, 2018 plasma bubble by CSES-01 satellite

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Summary. — Equatorial Plasma Bubbles (EPBs) are plasma density depletions observed in the equatorial ionosphere. The correct understanding of the EPBs dynamics and formation has a key role in the Space Weather context. This work reports the analysis of a nightside EPB detected in the African sector during a solar quiet period on August 14, 2018. The principal characteristics of the EPB have been identified by the use of the electric field detector, fluxgate magnetometer and Langmuir probe on board CSES-01 (China Seismo Electromagnetic satellite). The results show that a peculiar solar wind structure is likely at the base of the EPB generation.

1. – Introduction

Plasma density depletions, which are observed in the equatorial ionosphere at different spatial ($\sim$ 50–1000 km) and temporal scales, are called Equatorial Plasma Bubbles (EPBs). Typically, EPBs are detected within $\pm 20°$ dip latitude, between the bottom side of the ionospheric F layer up to $\sim$ 1000 km [1]. In general, EPBs occur at post-sunset and at post-midnight hours [2]. For the first, after local sunset, at low latitudes the so-called pre-reversal enhancement of the equatorial anomaly [1] generates an upward plasma drift and, if the Rayleigh-Taylor instability growth rate is large enough, plasma irregularities can be generated [3]. When a geomagnetic storm occurs, electric field perturbations can be generated by prompt penetration electric fields (PPEFs) of magnetospheric origin and/or by the so-called ionospheric disturbance dynamo [4]. The post-midnight EPBs are usually a consequence of a long living post-sunset EPB. Anyway they can also be generated as a consequence of both peculiar solar wind condition [5], and the regular variation of the EEJ due to seasonality, solar flux and tidal waves of lower atmospheric origin [6].

This paper presents the analysis of an EPB detected during a solar quiet period. The main parameters of the bubble (plasma drift velocity, density), are derived by using electric (EFD, [7, 8]) and magnetic field instruments (HPM, [9]) and Langmuir probe (LAP, [10]) on board CSES-01 [11]. Finally, according to the approach of Piersanti *et al.* [5], we identified the cause of its generation using SW parameters observed in the interplanetary space.

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2. – CSES-01 satellite observations

On August 14, 2018 CSES-01 detected a strong plasma depletion, as visible in fig. 1 that shows the principal bubble features, evaluated using EFD, LAP and HPM instruments on board the satellite. Panel (a) shows the satellite semiorbit (solid black line) during which the EPB has been observed (thick grey line). The great latitudinal extension of the plasma irregularity ($\sim 20°$) can be easily appreciated. The electric field observations show a strong decrease (~ -0.45 V/m) along the north-south direction (X component, in panel (b)) coupled with an increase along the east-west direction (Y component, in panel (c)), while the vertical component (panel (d)) presents a negative variation preempted by a sudden positive excursion. Correspondingly, the LAP observed a huge plasma density decrease, panel (e) (from $\sim 2 \cdot 10^{10}$ cm^{-3} to $\sim 8 \cdot 10^7$

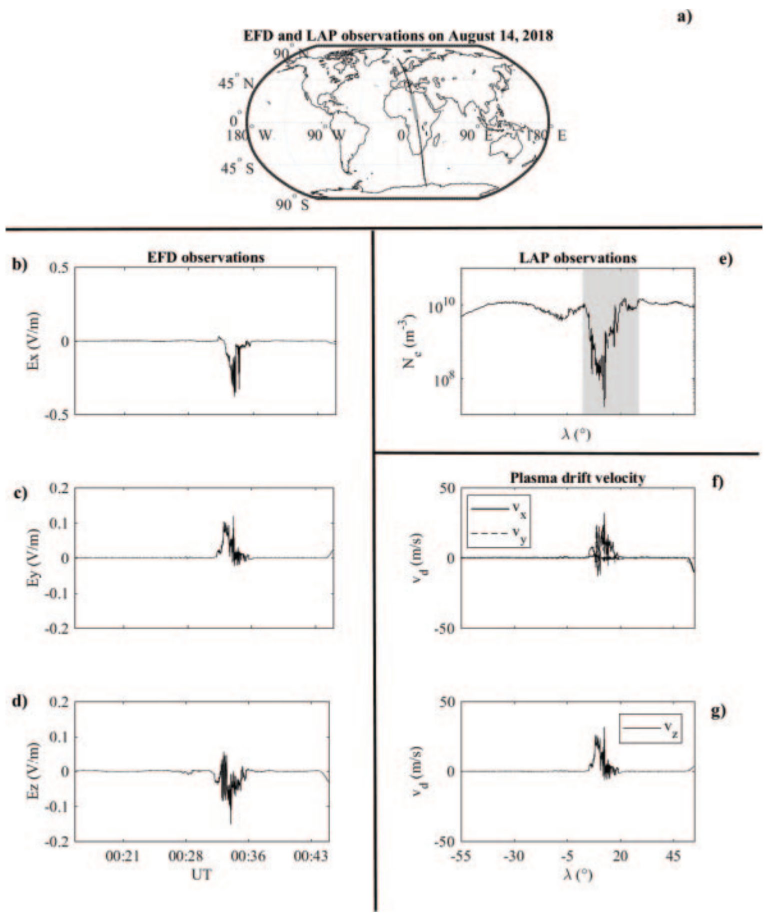

Fig. 1. – EFD and LAP observations by CSES-01 satellite on August 14, 2018. Panel (a) shows the location of the investigated orbit (solid black line) between 00:17 and 00:46 UT. The thick grey part underlines the time interval in which the EPB was detected by CSES-01. Panels (b), (c) and (d) display the electric field components. Panel (e) shows the electron density profile measured by the LAP. Panels (f) and (g) show the horizontal and the vertical plasma drift velocities. All components were expressed in the geographical reference frame. The grey shaded region represents the identification of the PB.

cm^{-3}). We need to remark here, that, following the approach of Diego *et al.* [8], the electric field due to the spacecraft motion into the geomagnetic field has been removed from the EFD observations. The concomitant presence of both electric and magnetic field instruments on board CSES-01 allows to evaluate the local plasma drift velocity ($\vec{v_d} = \vec{E} \times \vec{B}$). The plasma density depletion easily appears to be related to an uplift of the ionosphere, as highlighted by the vertical component of the plasma drift velocity, shown in fig. 1(g). In addition, it results that the EPB is moving westward, as highlighted in fig. 1(f).

3. – Discussion and conclusions

In order to identify a possible physical process for the generation of the August 14, 2018 EPB, we collected solar wind (SW) parameters as close as possible to the Earth. To this purpose we analyzed the observations made by THEMIS-C satellite (fig. 2).

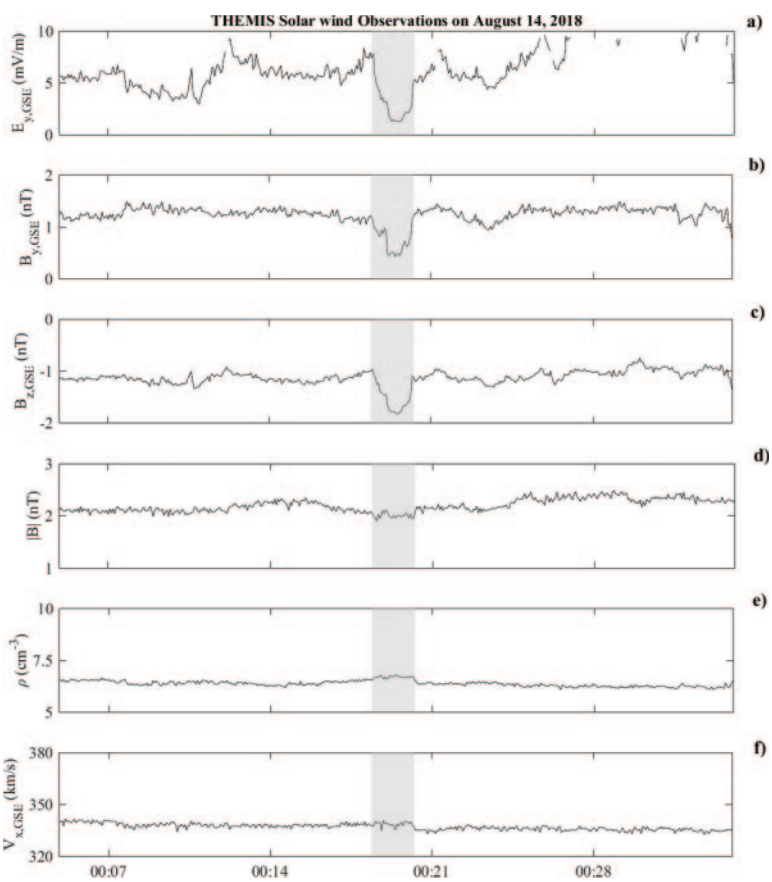

Fig. 2. – THEMIS-C solar wind observations: (a) Y_{GSE} component of the interplanetary electric field; (b) Y_{GSE} component of the interplanetary magnetic field; (c) Z_{GSE} component of the magnetic field; (d) total interplanetary magnetic field; (e) plasma density; (f) X_{GSE} component of the plasma velocity. All components were expressed in the geocentric-solar-ecliptic (GSE) reference frame.

Figure 2 shows that between 00:05 UT and 00:34 UT THEMIS-C was in the interplanetary space, since it is measuring values of plasma density (panel (e)) and plasma velocity (panel (f)) that are consistent with the SW observations at the first Lagrangian point [4]. Between 00:19 UT and 00:20 UT (grey shaded region), THEMIS-C detected a strong and sharp variation along both the electric field (panel (a)) and the magnetic field (panels (b), (c)). This kind of SW structure can be identified with a rotational discontinuity [12] as confirmed by the constant values of SW density, velocity and total magnetic field (panels (d), (e) and (f)).

Through a direct comparison between the occurrence time of the ionospheric EPB (fig. 1(e)) and the SW structure detected by THEMIS-C (fig. 2, grey shaded region), we found a delay time of 19 ± 1 minutes. Being this delay consistent with the transmission time of the interplanetary electric field to the equatorial ionosphere [5], it is possible to suppose a direct connection between the SW structure, identified by THEMIS-C, and the generation of the EPB, detected by CSES-01. Specifically, the interplanetary electric field variation, induced by the rotational discontinuity and lasting for few minutes, impinging on the magnetosphere, led to an undershielding condition of the R1 and R2 FACs, generating an eastward PPEF propagating towards equatorial latitudes. Such PPEF, superimposed to the local equatorial electric field [13], gave rise to a significant ionospheric plasma uplift, which in turn causes the observed EPB [14]. Anyway, it is worth highlighting that such kind of EPB could be caused by the regular variation of the EEJ due to seasonality, solar flux and tidal waves of lower atmospheric origin [6]. A further investigation is needed to clarify this aspect.

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