# Comparison of HSS and CME Influences on F2-layer based on Storms in October 2005

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*In the present paper, we study HSS and CME effects on the ionosphere. Each type has different ability to affect the geosphere. Our study is focused on the effects occuring during the last solar minimum. Two solar events in October 2005 were selected to study the ionospheric response above the Athens, Chilton, Dourbes, Juliusruh, Pruhonice and Roquetes observatories. Within the storms occuring in the solar minimum we selected two events (HSS: 7 Oct 2005, 19UT and CME: 31 Oct 2005, 18UT, by means of Dst) and analysed their influence on the ionosphere. The magnetospheric response by means of Kp and Dst was similar in both events.*

*Within the ionospheric parameters we selected foF2 and h'F. The HSS event is followed by a significant decrease in foF2 values in the duration of 2 days. No change is observed for night foF2 in this case.The response to the CME is much weaker than to the HSS and less change in foF2 is observed. Both events are followed by h'F oscillations which may indicate Travelling Ionospheric Disturbances (TID).*

## Introduction

Ionosphere is a highly variable system. The solar and geomagnetic activity, as well as dynamic events in the neutral atmosphere heavily influence its state. Disturbances of the ionospheric plasma affect operation of various communication and navigation systems, e.g. GPS, GALILEO, Glonass [1]. Response of the ionospheric plasma to the solar events is widely studied. The ionospheric storms, their drivers and mechanisms how are they connected to the magnetosphere are described in detail for example in [2], [3], [4].

Current solar minimum lasts for an unusually long time. It allows us to study the ionosphere under special conditions as it stays in exceptionally quiet state. Such a prolonged, exceptionally low solar minimum gives us unique opportunity to study ionospheric response to the solar events as they are relatively isolated in the time.

High Speed Solar Stream (HSS) is characterized by poloidal magnetic field. HSSs are formed in the areas of solar coronal holes that are long lived regions of open magnetic field lines. The solar wind flowing from them has high speed, low plasma density and high plasma temperature.

Coronal Mass Ejection (CME) is characterized by toroidal magnetic field. CMEs originate in the regions of closed magnetic field lines rooted at both sides in the Sun. CMEs have low proton temperature (low plasma beta) [5], [6], [7]. It has been shown that these different types of solar events influence differently the Earth's magnetosphere. A term 'geoeffectiveness' has been introduced to describe this influence [8], [9].

The task of our paper is to investigate ionospheric response to onset of each of the events under special conditions of current prolonged solar minimum and compare the response with the results of [10] at the Pruhonice station.

## Data

We have selected two solar events from October 2005, HSS and CME, and we have studied ionospheric responses at six ionospheric observatories.

As mentioned above, this solar minimum is convenient for studies of ionospheric behavior under special conditions. On the other side, it is very difficult to find solar events with proper characteristics as especially CMEs are very rare in present solar minimum. The criteria how to choose similar solar events are: type of the event, the magnitude of magnetic field **B**, season, time of a storm onset and availability of ionospheric data as during the storm some ionograms can be difficult or impossible to scale. It was difficult to find events that satisfy all our criteria as especially CMEs are relatively rare in present solar minimum.

According to the definition of HSS ($v>500$ km·s$^{-1}$ and increase of velocity of more than 100 km·s$^{-1}$ within one day, accompanied by high plasma temperature and low plasma density) and CME (high magnetic field, low beta) [5], we have chosen the HSS event of October 07, 2005, 02 UT and the CME event of October 31, 2005, 03 UT (times of solar events on the satellite). Measurements of magnetic field, plasma density and solar wind velocity were made by the ACE satellite, publicly available in the NASA CDAWeb database (http://cdaweb.gsfc.nasa.gov/). Total magnetic field **B**, magnetic components in GSE Bz and velocities are shown in Fig. 1 and Fig. 2. Both events are characterized by $B_z$ negative. The change of solar wind parameters is first detected on the ACE satellite. The beginning of geomagnetic response/disturbance by mean of Dst is detected on observatories with a ~1hour delay.

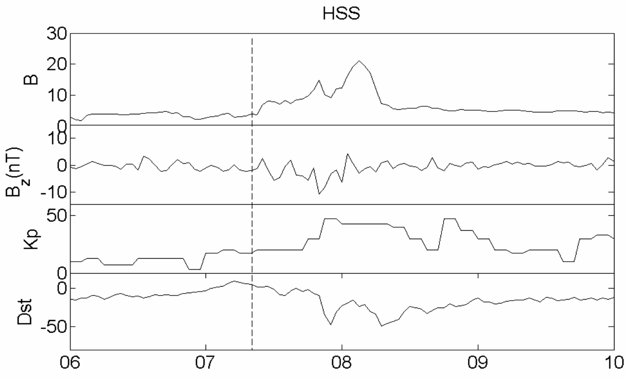


*Fig. 1 HSS, Oct 07, 2005*

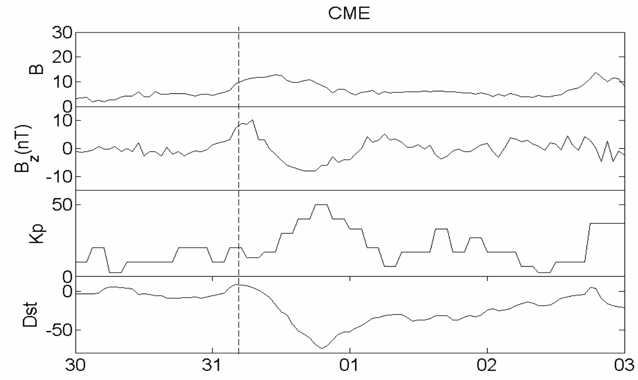


*Fig. 2. CME, Oct 31, 2005*

The events have similar properties (magnitude of **B**, time of beginning etc.). The Dst reaches similar value (Fig. 1 and Fig. 2).

For both events we use data from the DIDB database http://ulcar.uml.edu/DIDBase/. For each event, we use manually processed 6-8 days of ionograms with the regular 15 (or 10) minute cadence (Pruhonice, Chilton, Roquetes) or automatically scaled data with a manual correction (Athens, Dourbes, Juliusruh). As a reference we use one day prior to the event. We study the ionospheric response during following days after the event. From ionograms, we estimated critical frequencies foF2 which correspond to the maximum electron concentrations in ionospheric plasma, and virtual heights of bottom of the F layer h'F. The values h'F are computed straight from the time of flight of the reflected electromagnetic signal under assumption that its velocity equals to the velocity of light [11].

## F-layer ionospheric response

***Response to the HSS:***

Maximum daily critical frequencies first show light increase one day after the event and then decrease of about 20 percent during days two and three after the event. This decrease is significant in all studied digisonde records. The foF2 then return back to previous values. No important change in the night foF2 values is observed (Fig. 3 top). The values h'F exhibit relative increase during night after the event in comparison to the reference time for stations Dourbes, Chilton, Juliusruh, Roquetes and Pruhonice (see Fig. 3, bottom). The values h'F show oscillations which may indicate passing of Traveling Ionospheric Disturbances (TIDs) [12], [13] from the polar to the equatorial areas along the magnetic field lines.

***Response to the CME:***

Ionospheric response in the observed foF2 is weaker than in the HSS event. Less pronounced change in both day and night values is present after the event (Fig. 4 top).

Values of h'F exhibit oscillations for ~4 days after the event as well as an increase of night h'F. Mean day values do not show significant change (Fig. 4 bottom).

## Conclusion

Two solar events from October 2005 and their ionospheric responses are analyzed. This work continues with the studies of solar events [14] and their effect on the ionosphere [8], [10] and references therein.

HSS causes significant decrease of daily foF2 two and three days after the event and no important change in night foF2. Oscillations of h'F may indicate TIDs which may have been caused by the fast particles of HSS coming to the magnetosphere of the polar areas. This event was much weaker by means of the ionospheric response in comparison to the event studied in [10] although the Dst and Kp indices are comparable. It supports the idea that Dst indices may be insufficient for ionospheric modeling and forecasting.

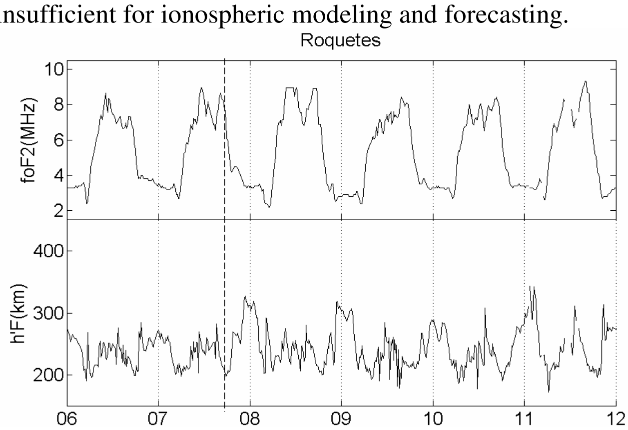


*Fig. 3. HSS, Oct 07, 2005. Top figure shows ionospheric response to the event by means of foF2. Slight increase of foF2 one day after the event and decrease in days two and three are detected. Bottom: increase in night values of h'F and oscillations follow the HSS event.*

CME event causes less pronounced change in day and night foF2, although the responding Dst and Kp indices could have imply more serious change in ionospheric characteristics. Virtual heights h'F exhibit oscillations similar to the HSS event. In our previous work we found relatively strong effects of Magnetic Clouds to the ionosphere [10]. CME event present supports the results of [8] and [9] that CMEs without rotational magnetic field are much weaker in their ability to affect the ionosphere by means of the term "geoefectiveness".

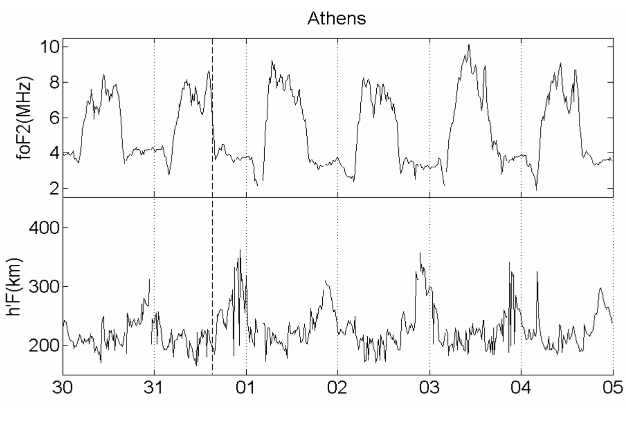


*Fig. 4. CME, Oct 31, 2005. Top figure: Less pronounced change in foF2 after the event. Bottom: Increase of h'F during night in comparison to reference days. Oscillations are present after the solar event.*

It calls for a statistical study of HSSs and their ability to affect the ionosphere during current "prolonged" solar minimum.

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