



Observation of ionospheric irregularities in Southern Spain during moderate geomagnetic storms using digisonde and GNSS receivers' data

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It is well known that ionosphere F-region irregularities originate at night near the geomagnetic equator and they rise in altitude and, following the magnetic field lines at high altitudes, reach latitudes far away from the equator. The scale size of these irregularities ranges from centimetres to kilometres [1]. F-region irregularities were discovered first with ionosonde observations at equatorial and low geomagnetic latitudes that showed the presence of diffuse echoes (Spread-F) due to the existence of such irregularities. This phenomenon is related to the presence of the so-called ionospheric plasma bubbles. [2], using GNSS receivers derived total electron content (TEC) and Swarm and DMSP satellites on board measurements, found for the first time that during the severe geomagnetic storm of 22-23 June 2015 large irregularities were observed in southern Europe (Spain, Portugal, Southern France and Italy). The same paper shows that the occurrence of irregularities during that storm is observed in the Western longitude of the African-European sector but not in the Eastern longitude of the same sector. Here, we describe the occurrence of irregularities observed in Southern Spain during two moderate geomagnetic storms: 26-27 February 2014 and 17-18 September 2021 that occurred at night in the European sector local time. Such a phenomenon was not observed at higher latitudes in Spain and at the longitude of Greece (Eastern longitude). Data used in the present investigation are digisonde observations from El Arenosillo (Spain), Roquetes (Spain) and Athens (Greece) and GNSS derived TEC from receivers located near-by the digisonde locations. To analyse the occurrence of such a phenomenon, ROTI (TEC rate of change index) values are calculated from TEC measurements, and Spread-F occurrence from digisonde ionograms is used. ROTI was introduced as a measure of ionospheric irregularities from GNSS derived TEC values by [3]. The results obtained are in agreement with the observations of [2] and with those of [4]. These last authors indicated the presence of irregularities during the night local time moderate geomagnetic storm of 8-9 October 2013, using ROTI data from GNSS receiver stations located at low geomagnetic latitudes in Western Africa and, essentially, the absence of such a phenomenon in Eastern Africa. It is well known that the presence of irregularities appears to be more relevant at low geomagnetic latitudes during geomagnetic storms occurring at night local time. Note that geomagnetic storms of larger intensities in terms of Dst, but occurring in daytime Europe local time, do not show any occurrence of Spread-F in the corresponding ionograms of El Arenosillo, Roquetes and Athens or significant increase of ROTI in the TEC data from the near-by receiver sites. All the results are discussed in terms of the possible physical processes involved.

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