



## **Automatic detection of Spread F at the ionospheric station of Tucumán and climatology from massive statistical analysis of data**

Carlo Scotto\* <sup>(1)</sup>, Dario Sabbagh<sup>(1)</sup> and Alessandro Ippolito <sup>(1)</sup>

(1) Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143, Rome, Italy, e-mail: carlo.scotto@ingv.it; dario.sabbagh@ingv.it

The Autoscala software was improved introducing a routine for automatic detection of diffused echoes known as Spread F, which appear in ionograms due to the presence of ionospheric irregularities along the radio signal path. The routine is based on an image recognition technique and was tested to the ionograms recorded at the low-latitude ionospheric station of Tucumán (26.9° S, 294.6° E, magnetic latitude 15.5° S, Argentina) in 2016 [1]. The performance achieved was statistically evaluated and demonstrated with significant examples. The method improved Autoscala's ability to reject ionograms with insufficient information, including those featuring Spread F. Automatic identification of cases of Spread F is of additional interest in Space Weather applications, when it helps to detect degraded radio propagation conditions. A data analysis was then performed as a retrospective study to form the basis for real-time application as an extension of Autoscala's capabilities. Indeed, although the main objective of this routine is to reject bad quality ionograms, automatic ionogram interpretation methods developed for real-time ionospheric monitoring can also be applied in retrospective studies to analyze large quantities of data for geophysical studies. This new capability was used in a climatological study including a large number of ionograms recorded at Tucumán [2]. The study took into account different levels of geomagnetic and solar activity from 2012 to 2020. The results demonstrate the capability of Autoscala to capture the main signature characteristics of Spread F and the temporal evolution of the ionosphere peak height  $h_mF2$ , capturing the post-sunset plasma surge that precedes the development of Spread F. Maximum occurrence of Spread F is observed in local summer, with a tendency to shift before midnight with increasing solar activity. Other new climatological details that emerged from the study are here presented, on the connection with geomagnetic activity, and the morning  $h_mF2$  behavior after extremely marked nighttime Spread F occurrence.

### **References**

1. C. Scotto, A. Ippolito, and D. Sabbagh, "A method for automatic detection of equatorial spread-F in Ionograms," *Adv. Space Res.*, **63**, 1, 2019, pp. 337–342, doi:10.1016/j.asr.2018.09.019.
2. C. Scotto, and D. Sabbagh, "Climatology of Spread F over Tucumán from Massive Statistical Analysis of Autoscaled Data," *Atmosphere*, **12**, 10, 2021, 1351, doi:10.3390/atmos12101351.