Long-term spread F morphology over Europe

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Introduction

- During daytime, midlatitude plasma distribution is mainly controlled by diffusion, neutral wind shear and strong polarized electric fields. The poleward neutral wind drives the plasma density towards lower altitudes whereas the opposite effects are caused by meridional wind. During nighttime, reduced plasma density limits the interaction with neutral wind, which in turn gives rise to nighttime plasma motion in the F region of midlatitude ionosphere [1].
- In the midlatitude ionosphere, the occurrence of nighttime spread F is frequent, when compared with both high (≥60°) and equatorial (0°-±30°) latitude regions [2].

Objective & Data & Methodology

- The present study aims to investigate the temporal variation of spread F statistics perhaps for the first time over low-to-midlatitude transition region covering the eastern Mediterranean longitude sector by employing Digisonde measurements at Nicosia (Cyprus) (geographic Lat: 35.19°N, Long: 33.38°E geographic; Geomagnetic. dip: 29.38°N), Athens (Greece) (geographic Lat: 37.98°N, Long: 23.73°E geographic; Geomagnetic. dip: 34.61°N) and Pruhonice (Czech Republic) (geographic Lat: 50.05°N, Long: 14.41°E geographic; Geomagnetic. dip: 47.70°N) during the years of 2009, 2015 and 2016.

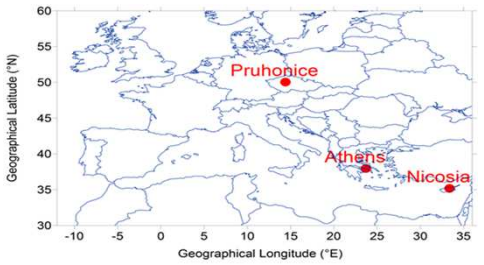

Figure 1. Map showing location of the three mid-latitude ionospheric stations involved in the study.

Results - Diurnal and seasonal variability of spread F

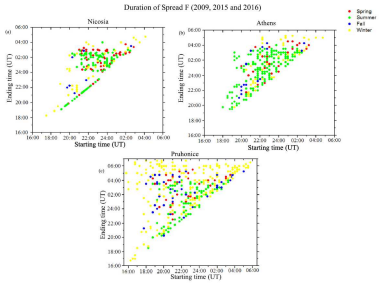

Figure 2. Diurnal variation of spread F occurrences for different seasons. The x axis represents the onset time of spread F between the time intervals of 16:00 UT to 06:00 UT of the next day and the y axis stands for the ending time of spread F between the time intervals of 16:00 UT to 06:00 UT of the next day. the number of green dots appears to be the highest followed by yellow and blue dots which signifies that over Nicosia, the occurrence of spread F maximizes during summer followed by winter and spring. A very limited number of spread F cases have been recorded during fall. Another interesting behavior that can be identified is that during winter the duration of spread F maximizes followed by summer and spring. In spring, maximum number of cases for spread F onset was observed during postmidnight periods whereas in summer and winter, the onset time is distributed all over the plot

Results - Effect of solar activity in spread F occurrence

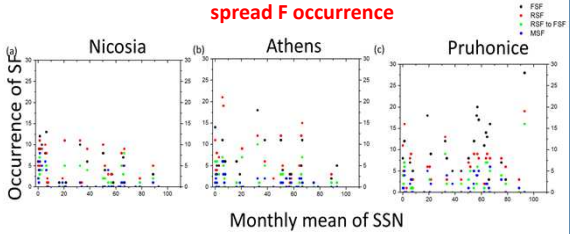

Figure 3: Solar activity dependence of different spread F types. Over Nicosia, the spread F occurrence maximizes for sunspot number less than 20. A secondary maximum is also noted for FSF and RSF within a sunspot range of 50 to 60. In Athens during low solar activity, the monthly occurrence of RSF maximizes whereas at moderate solar activity FSF was more frequent. RSF development maximizes during low solar activity at Pruhonice, but unlike Nicosia and Athens, during high solar activity, RSF is present. Since 2015 was a high solar activity year with sunspot number 60-90, a significant number of RSF cases were noted.

Results - Monthly variation of different spread F types

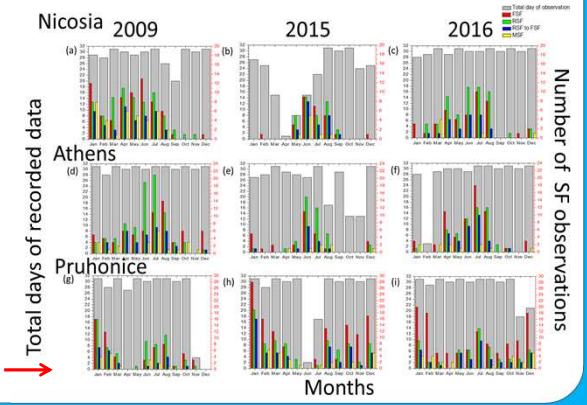

Figure 4. Monthly variation of different spread F types. In Nicosia and Athens on 2009, 2015 and 2016 higher occurrence of spread F can be observed in summer followed by January. RSF was the dominant spread F type observed over this station. In Pruhonice an annual maximum of spread F occurrence can be identified in winter, especially during January-February, and a secondary maximum appears during summer.

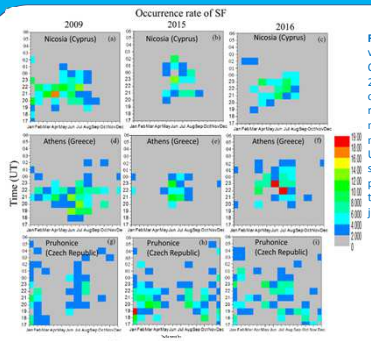

Figure 4: Diurnal and seasonal variation of different spread F types. Over Nicosia on April during 20:30 to 21:30 UT, maximum overall spread F occurrence (around 18 cases) were registered. Over Athens the maximum occurrence of spread F was noted during summer around 19:00 UT to 23:00 UT. During winter solstice, Pruhonice exhibits mostly premidnight spread F despite the fact that some spread F cases were noted just after the post-sunset periods.

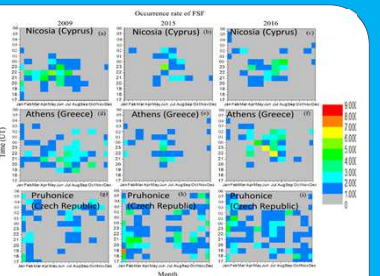

Figure 5. Diurnal and seasonal variation of FSF observed from Nicosia Athens and Pruhonice on 2009, 2015 and 2016.

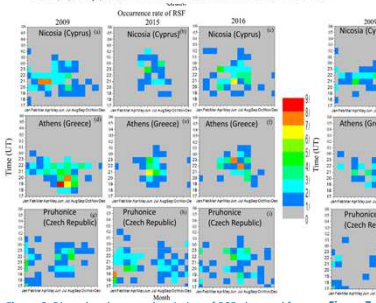

Figure 6. Diurnal and seasonal variation of RSF observed from Nicosia, Athens and Pruhonice on 2009, 2015 and 2016.

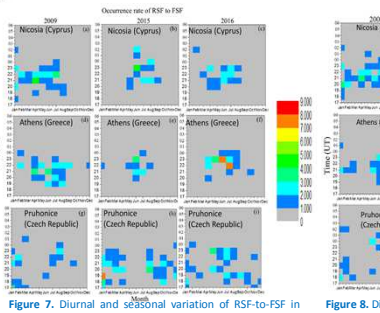

Figure 7. Diurnal and seasonal variation of RSF-to-FSF in Nicosia, Athens and Pruhonice on 2009, 2015 and 2016.

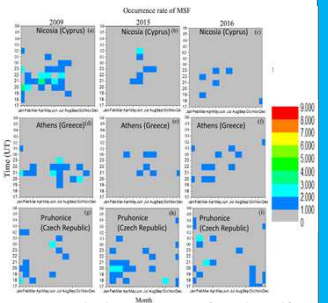

Figure 8. Diurnal and seasonal variation of MSF observed from Nicosia, Athens and Pruhonice on 2009, 2015 and 2016.

Table 2. Percentage observations of different signatures prior to the common spread F occurrence.

Year	Station combinations used	Unstable Es (%)	LSWS (%)	GPS-TIDs (%)	Vz-TIDs (%)	F layer uplift (%)
2009	Nicosia-Athens	76.74	86.05	34.88	53.49	62.79
	Athens-Pruhonice	76.92	61.54	46.15	46.15	53.85
	Nicosia-Athens-Pruhonice	–	–	–	–	–
2015	Nicosia-Athens	86.67	73.33	53.33	53.33	53.33
	Athens-Pruhonice	37.50	37.50	25.00	62.50	62.50
	Nicosia-Athens-Pruhonice	66.67	66.67	0.00	66.67	33.33
2016	Nicosia-Athens	58.06	70.97	67.74	61.29	54.84
	Athens-Pruhonice	54.55	54.55	45.45	54.55	72.73
	Nicosia-Athens-Pruhonice	16.67	50.00	16.67	50.00	50.00

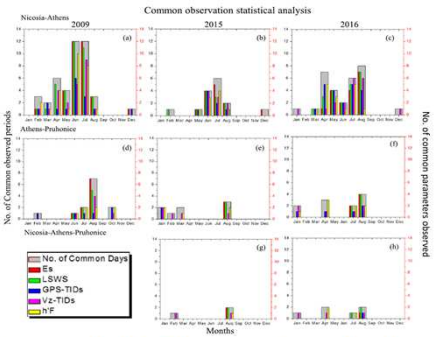

Figure 9. Statistical analysis for different parameters and precursors observed prior to the common spread F observation from (a) Nicosia and Athens on 2009 (b) Nicosia and Athens on 2015 (c) Nicosia and Athens on 2016 (d) Athens and Pruhonice on 2009 (e) Athens and Pruhonice on 2015 (f) Athens and Pruhonice on 2016 (g) Nicosia, Athens and Pruhonice on 2015 (h) Nicosia, Athens and Pruhonice on 2016.

Over Nicosia-Athens in 2009, 47 common (onset of spread F at the same time interval observed over Nicosia and Athens) were noted.

In 2015 and 2016,

- 16 and 37 common nighttime spread F events were observed over these two stations respectively.
- 13 common spread F events were noted from Athens and Pruhonice during 2009. In 2015 and 2016, the numbers of common spread F cases were 8 and 11 respectively.
- 3 and 6 common spread F events were noted from Nicosia, Athens and Pruhonice in 2015 and 2016 respectively.

Conclusions

❖ A clear inverse correlation was observed between the occurrence rate of spread F events with solar activity at lower midlatitude regions (<50°N), as is well established in literature [2, 3, 4, 5]. But at higher midlatitude regions (>50°N), the exact opposite phenomenon is noted. In Pruhonice (situated beyond 50°N) the occurrence rate of spread F events increases with solar activity [2].

❖The annual maxima of spread F occurrence over the lower midlatitude region (<50°N) are found during summer solstices and are independent of solar activity followed by a secondary maximum, which depends on solar activity. During high solar activity, no secondary maxima were detected, whereas during solar minimum, the secondary maximum was observed during winter. At moderate solar activity, it shifted to spring.

❖During high solar activity, nighttime F region of the lower midlatitude regions is mostly characterized by RSF, whereas FSF plays the dominant role at higher midlatitudes [2,3].

❖ Longitudinal variation in spread F events observed between Nicosia and Athens was insignificant. Most probably the main instability triggering mechanisms were the electrodynamic coupling effect between Es and the bottom of F layer, and the F layer uplift (h'F). LSWS signatures were notably observed from both these regions.

❖Latitudinal differences in spread F were very prominent between Athens and Pruhonice [2]. The main instability triggering mechanisms were Vz-TIDs and F layer uplifts (h'F). Prominent impact of the electrodynamic coupling between Es and F layer was also noted during low solar activity to initiate the instability at higher midlatitudes.

References

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