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Effect of Total, Northern and Southern Hemisphere Sunspot Number (Ri, Rn and Rs) on F2- Layer Critical Frequencies at Mid- Latitude Rome Station During the Descending Phase of Solar Cycle 23

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Abstract

The relationship between F2- layer critical frequencies (foF2), total sunspot number (Ri), northern hemisphere sunspot number (Rn) and southern hemisphere sunspot number (Rs) at station located in mid- latitudes on latitude near to latitude of Iraq (Rome station, lat.: 42^o N and lon.: 13^o E) and for 2003(the descending phase of solar cycle 23) were studied.

This research work aims to know the correlation range between them, through correlation coefficients which correlate between them, and hence, the dependence on that index for predicting F2- layer critical frequencies. When the correlation coefficients between foF2, Ri, Rn and Rs were compared for different seasons of 2003, It is found that, correlation coefficient between foF2 and Ri is higher in Winter and Summer than it between foF2, Rn and foF2, Rs in Winter and Summer, too. While, correlation coefficient between foF2 and Rn is higher in Spring and Autumn than it between foF2, Ri and foF2, Rs in Spring and Autumn, too. Also, it is found that, the correlation coefficients between foF2, Ri and foF2, Rn and foF2, Rs were so small that foF2 values are approximately constant as Ri, Rn and Rs values increased, in Autumn.

Keywords: F2- layer critical frequencies, Total sunspot number, Northern hemisphere sunspot number, Souther hemisphere sunspot number.

تأثيرعدد البقع الشمسية الكلي(Ri)، عدد البقع الشمسية الواقعة في النصف الشمالي و الجنوبي من الشمس(Rn and Rs) على الترددات الحرجة لطبقة F2 عند محطة روما خلال الطور المنخفض من الدورة الشمسية 23

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الخلا صة

تم دراسة العلاقة البيانية بين قيم الترددات الحرجة لطبقة F2 (foF2)، عدد البقع الشمسية الكلي(Ri)، عدد البقع الشمسية في النصف الشمالي من الشمس(Rn) و عدد البقع الشمسية في النصف الجنوبي من الشمس(Rs) عند محطة واقعة في خطوط العرض الوسطى على خط عرض قريب الى خط عرض العراق(محطة روما ، خط عرض: 42^o شمالا و خط طول: 13^o شرقا) و للسنة 2003 (الطور المنخفض من الدورة الشمسية 23). يهدف هذا البحث الى معرفة مدى الترابط بينهم، من خلال معاملات الترابط التي تربط بينهم و من ثم الاعتماد على ذلك المعامل لتنبؤ قيم الترددات الحرجة لطبقة F2 . عند مقارنة معاملات

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الترابط بين foF2 ، Ri ، Rn و Rs لفصول مختلفة من عام 2003 ، وجد بأن معامل الترابط بين foF2 و Ri يكون اعلى في فصلي الشتاء و الصيف منه بين foF2 و Rn ، foF2 و Rs في فصلي الشتاء و الصيف ايضا. بينما يكون معامل الترابط بين foF2 و Rn اعلى في فصلي الربيع و الخريف منه بين foF2 و Ri ، foF2 و Rs في فصلي الربيع و الخريف ايضا. وجد ايضا ان معاملات الترابط بين foF2 و Ri ، foF2 و Rn ، foF2 و Rs كانت صغيرة جدا بحيث تكون قيم foF2 ثابتة تقريبا كلما ازدادت قيم Ri ، Rn و Rs في فصل الخريف

Introduction

Sunspots are dark areas that grow and decay on the lowest level of the Sun that is visible from the Earth - the photosphere, which is referred to as the sun's surface. Sunspots are darker than their surrounding area because they are cooler than the average temperature of the solar surface (about 6000 degrees Kelvin). The appearance and disappearance of sunspots is due to underlying changes in the magnetic fields that exist throughout the Sun. The sun exhibits an extremely robust (reliable) periodic cycle of activity, going from very low activity at solar minimum to the highest activity at solar maximum then back to solar minimum again over an 11-year cycle. This is as an average value, but actual cycles have a period as short as 9 years or as long as 14 years. At the beginning of a solar cycle sunspots form between 30 and 50 degrees north (or south) of the solar equator. As each solar cycle progresses from its minimum to its maximum and on to a second minimum, sunspots form at progressively lower latitudes until by the second solar minimum sunspots are forming very close to the equator.

The Wolf number (also known as the International sunspot number, relative sunspot number, or Zürich number denoted by Ri) is a quantity that measures the number of sunspots and groups of sunspots present on the surface of the sun [1, 2, 3], [5, 6].

International sunspot number (total sunspot number, Ri) represents the sum of both of sunspot number in the northern hemisphere of the sun (denoted by Rn), and sunspot number in the southern hemisphere of the sun (denoted by Rs).

Data used

In the present study, hourly values of foF2 parameter scaled from the ionograms recorded routinely by the DPS-4 (Digital Portable Sounder) at Rome, Italy, were used at the website http://ulcar.uml.edu/DIDBase/. All recorded ionograms used for the present study were manually edited using the SAO Explorer software (SAO Explorer, Interactive Ionogram Scaling Technologies) developed by the University of Lowell Massachusetts, Center for Atmospheric Research [4].

Daily observed values of Ri, Rn and Rs for 2003 were obtained from Royal Observatory of Belgium, online at http://sidc.oma.be/index.php3.

Seasonal averages of each of foF2, Ri, Rn and Rs were deduced as illustrated in tables (1- 4) below. The linear relationship between them and for each season was drowning, as illustrated in figures (1-12) and the straight line equations were deduced. Finally, the correlation coefficients between them and the intersection points were deduced, as illustrated in tables (5-7).

Results and Discussions

Tables (1-4) illustrate the daily variations of F2- layer critical frequencies for Rome station and the corresponding values of total, northern hemisphere and southern hemisphere sunspot number (Ri, Rn and Rs respectively) at 12 UT and for different seasons of 2003.

Table 1- Daily variations of foF2, Ri, Rn and Rs at 12 UT during winter.

Winter(Dec., Jan., Feb.) - 2003					
Days	Time(UT)	foF2(MHz), average	Ri(average)	Rn(average)	Rs(average)
1	12	9.250	54.333	8.333	46.000
2	12	9.217	47.333	5.000	42.333
3	12	8.317	58.000	7.667	50.333
4	12	9.617	55.333	5.667	49.667
5	12	9.917	59.000	9.000	50.000
6	12	8.983	66.333	13.333	53.000
7	12	9.103	68.000	15.667	52.333
8	12	9.583	73.667	16.000	57.667
9	12	9.783	72.667	13.333	59.333
10	12	8.950	71.667	13.333	58.333
11	12	9.383	71.667	15.667	56.000
12	12	8.950	66.667	17.667	49.000
13	12	9.817	60.333	14.667	45.667
14	12	9.703	56.667	22.000	34.667
15	12	9.317	48.333	25.333	23.000
16	12	9.473	47.667	24.667	23.000
17	12	9.600	53.000	25.333	27.667
18	12	9.670	56.000	32.000	24.000
19	12	9.650	63.667	41.667	22.000
20	12	8.917	70.333	47.333	23.000
21	12	9.283	58.000	39.000	19.000
22	12	9.483	64.667	39.333	25.333
23	12	9.083	58.000	36.667	21.333
24	12	8.877	54.333	30.667	23.667
25	12	8.640	45.000	23.333	21.667
26	12	9.350	47.333	20.333	27.000
27	12	9.070	53.000	17.000	36.000
28	12	8.403	51.000	17.000	34.000
29	12	5.467	36.667	10.667	26.000
30	12	5.633	26.333	10.000	16.333
31	12	5.890	17.667	5.333	12.333

Table 2- Daily variations of foF2, Ri, Rn and Rs at 12 UT during Spring

Spring(Mar., Apr., May) - 2003					
Days	Time(UT)	foF2(MHz), average	Ri(average)	Rn(average)	Rs(average)
1	12	9.137	80.000	26.000	54.000
2	12	10.357	82.667	29.667	53.000
3	12	9.163	80.667	31.000	49.667
4	12	10.150	82.667	35.000	47.667
5	12	9.600	72.667	33.667	39.000
6	12	9.970	64.333	30.667	33.667
7	12	10.250	64.000	30.000	34.000
8	12	9.230	44.333	26.000	18.333
9	12	8.783	50.333	30.000	20.333
10	12	7.367	42.000	22.667	19.333
11	12	6.267	43.333	24.333	19.000
12	12	7.863	43.667	26.333	17.333
13	12	9.780	41.333	25.667	15.667
14	12	8.517	45.333	24.667	20.667
15	12	9.210	47.333	24.000	23.333
16	12	9.817	43.000	19.333	23.667
17	12	7.450	33.000	4.667	28.333
18	12	8.230	38.000	13.000	25.000
19	12	9.183	40.333	9.333	31.000
20	12	9.170	45.000	10.667	34.333
21	12	9.205	43.667	11.667	32.000
22	12	8.050	49.333	14.333	35.000
23	12	9.570	52.333	27.333	25.000
24	12	9.317	47.667	24.667	23.000
25	12	9.650	60.000	34.333	25.667
26	12	8.700	69.333	36.333	33.000
27	12	9.520	80.333	30.667	49.667
28	12	8.683	84.333	30.667	53.667
29	12	8.470	92.333	31.000	61.333
30	12	8.730	84.667	29.000	55.667
31	12	4.533	48.000	19.333	28.667

Table 3- Daily variations of foF2, Ri, Rn and Rs at 12 UT during Summer

Summer(Jun., Jul., Aug.) - 2003					
Days	Time(UT)	foF2(MHz), average	Ri(average)	Rn(average)	Rs(average)
1	12	7.190	63.667	38.000	25.667
2	12	7.413	63.667	41.000	22.667
3	12	7.983	65.333	43.667	21.667
4	12	7.240	62.333	42.333	20.000
5	12	6.865	67.333	45.000	22.333
6	12	7.157	77.333	51.000	26.333
7	12	8.013	87.000	47.333	39.667
8	12	6.757	86.333	40.667	45.667
9	12	6.935	90.333	42.000	48.333
10	12	7.840	85.667	30.333	55.333
11	12	7.800	83.000	25.000	58.000
12	12	7.940	84.667	21.333	63.333
13	12	7.500	87.333	27.000	60.333
14	12	8.003	80.000	25.333	54.667
15	12	6.657	78.333	30.333	48.000
16	12	8.125	78.333	27.000	51.333
17	12	6.150	80.667	35.333	45.333
18	12	7.135	85.333	38.333	47.000
19	12	7.135	87.333	37.000	50.333
20	12	6.573	99.000	42.667	56.333
21	12	5.937	88.667	44.333	44.333
22	12	7.743	84.333	40.667	43.667
23	12	7.693	80.667	46.000	34.667
24	12	6.903	76.000	48.667	27.333
25	12	7.107	68.333	49.667	18.667
26	12	7.090	66.333	50.000	16.333
27	12	7.580	72.000	52.333	19.667
28	12	8.180	79.333	55.333	24.000
29	12	7.180	74.000	48.000	26.000
30	12	7.320	68.000	47.000	21.000
31	12	4.657	35.667	19.667	16.000

Table 4- Daily variations of foF2, Ri, Rn and Rs at 12 UT during Autumn

Autumn(Sep., Oct., Nov.) - 2003					
Days	Time(UT)	foF2(MHz), average	Ri(average)	Rn(average)	Rs(average)
1	12	7.847	82.000	28.333	53.667
2	12	8.633	75.333	22.667	52.667
3	12	8.770	60.333	16.000	44.333
4	12	9.567	50.333	11.000	39.333
5	12	8.630	33.667	0.000	33.667
6	12	8.953	29.000	0.000	29.000
7	12	8.417	27.667	0.000	27.667
8	12	8.250	29.667	0.000	29.667
9	12	8.603	34.333	3.333	31.000
10	12	8.610	36.333	4.333	32.000
11	12	8.937	36.000	5.333	30.667
12	12	8.180	21.667	4.667	17.000
13	12	9.183	21.333	7.000	14.333
14	12	8.683	23.000	10.000	13.000
15	12	7.957	29.333	20.000	9.333
16	12	7.930	35.667	23.000	12.667
17	12	8.083	40.667	27.667	13.000
18	12	8.200	50.333	32.333	18.000
19	12	7.817	54.333	33.667	20.667
20	12	9.853	61.000	35.000	26.000
21	12	8.717	68.667	39.333	29.333
22	12	8.113	66.000	36.333	29.667
23	12	9.443	78.333	40.333	38.000
24	12	8.837	82.000	44.333	37.667
25	12	9.543	92.667	49.000	43.667
26	12	10.290	95.000	47.333	47.667
27	12	9.957	114.667	53.333	61.333
28	12	8.710	119.000	47.333	71.667
29	12	10.200	118.000	42.333	75.667
30	12	8.893	116.333	35.000	81.333
31	12	6.45	160	54	106

Figures (1-12) illustrate the linear relationship between seasonal daily averages of F2- layer critical frequencies, for Rome station, and the corresponding values of Ri, Rn and Rs, respectively, at 12 UT during 2003.

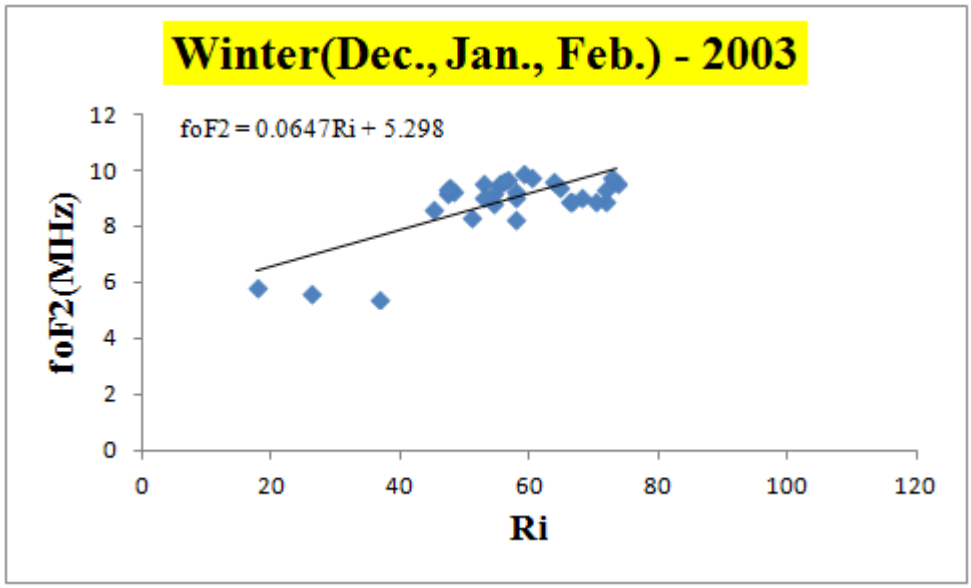

Figure 1- Daily average values of foF2 versus daily average values of Ri at 12 UT during Winter of 2003.

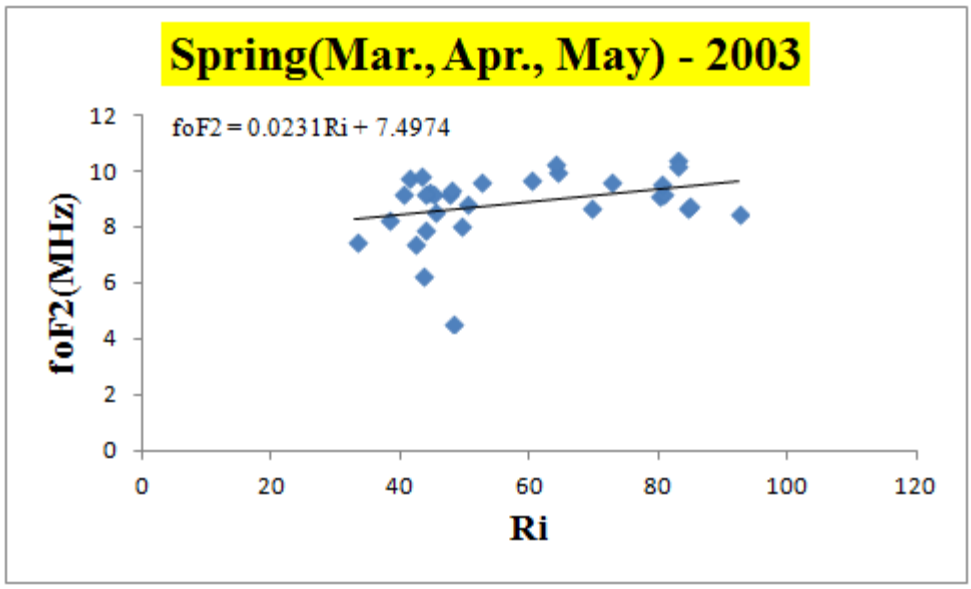

Figure 2- Daily average values of foF2 versus daily average values of Ri at 12 UT during Spring of 2003.

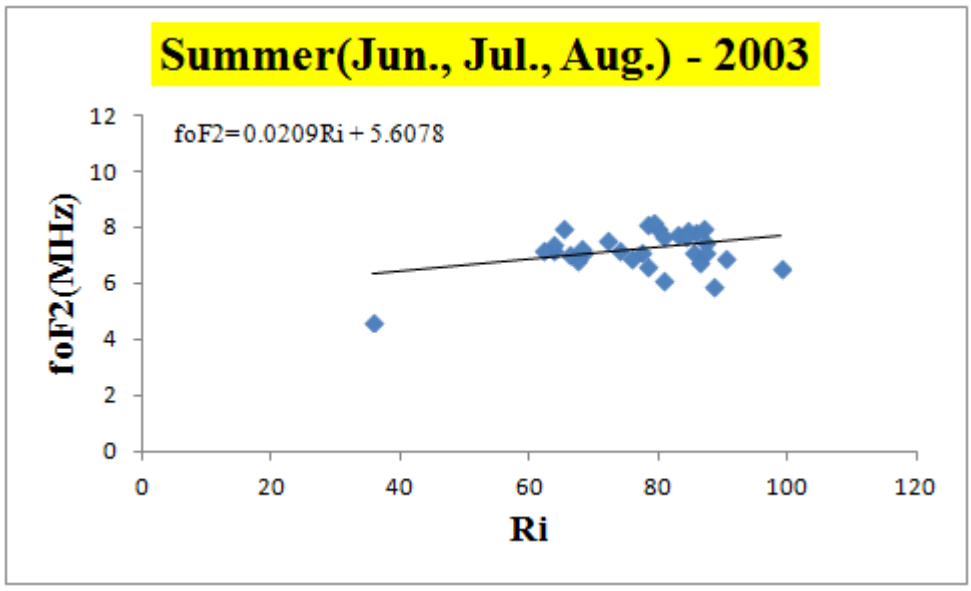

Figure 3- Daily average values of foF2 versus daily average values of Ri at 12 UT during Summer of 2003.

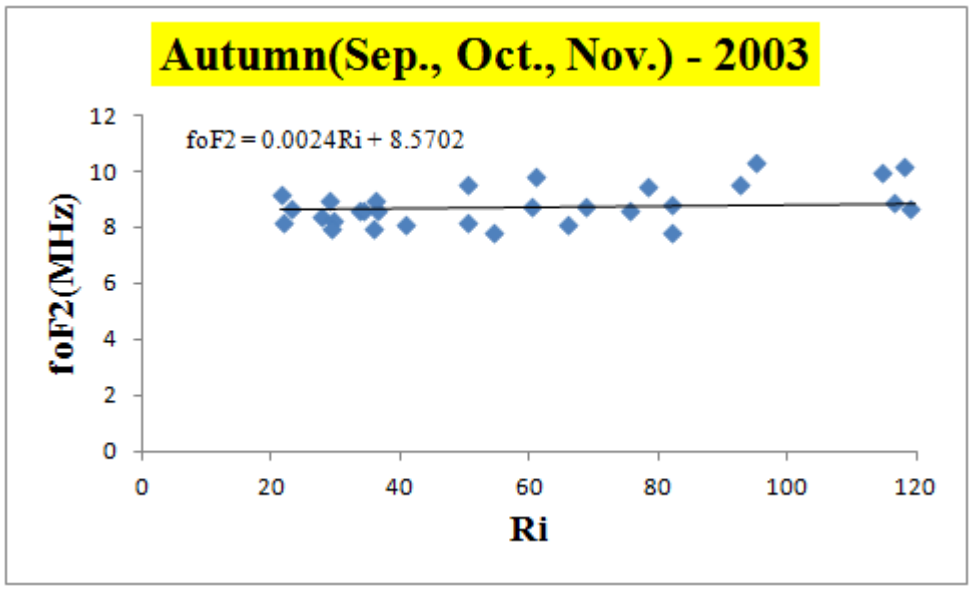

Figure 4- Daily average values of foF2 versus daily average values of Ri at 12 UT during Autumn of 2003.

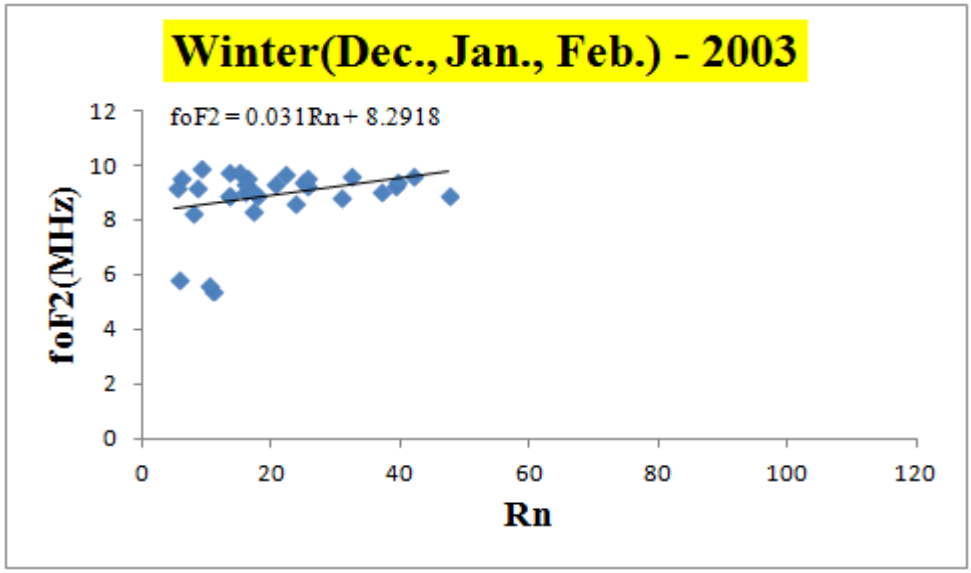

Figure 5- Daily average values of foF2 versus daily average values of Rn at 12 UT during Winter of 2003.

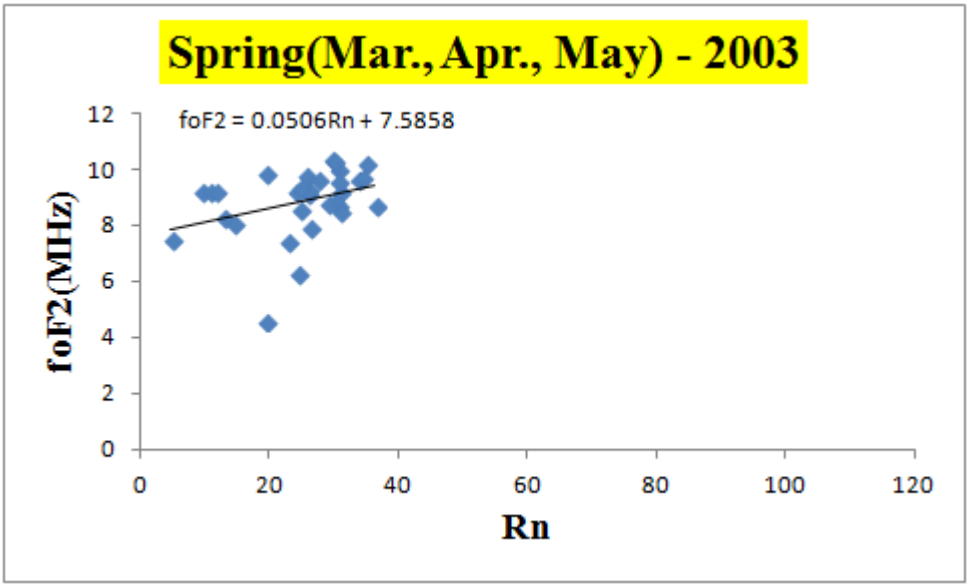

Figure 6- Daily average values of foF2 versus daily average values of Rn at 12 UT during Spring of 2003.

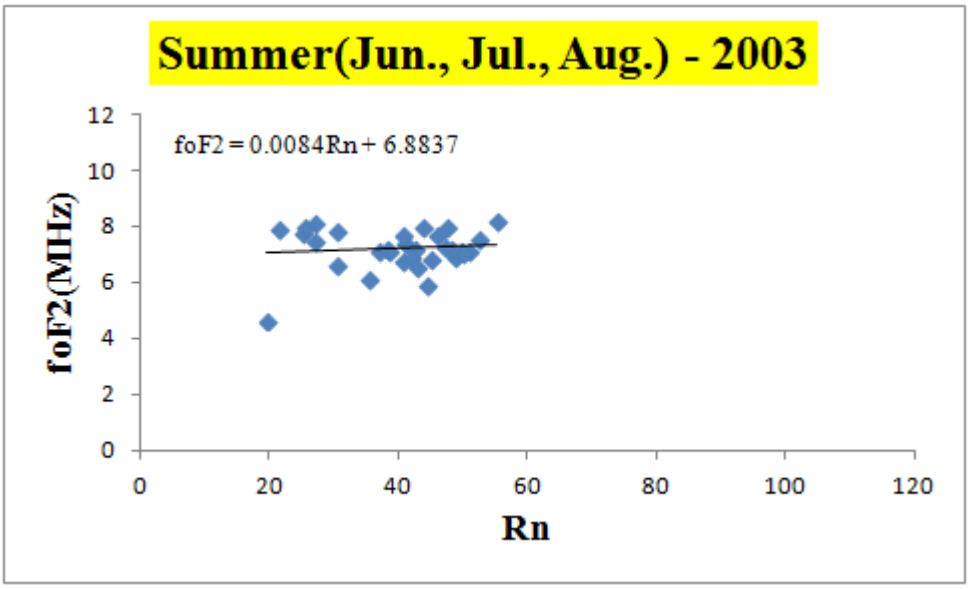

Figure 7- Daily average values of foF2 versus daily average values of Rn at 12 UT during Summer of 2003.

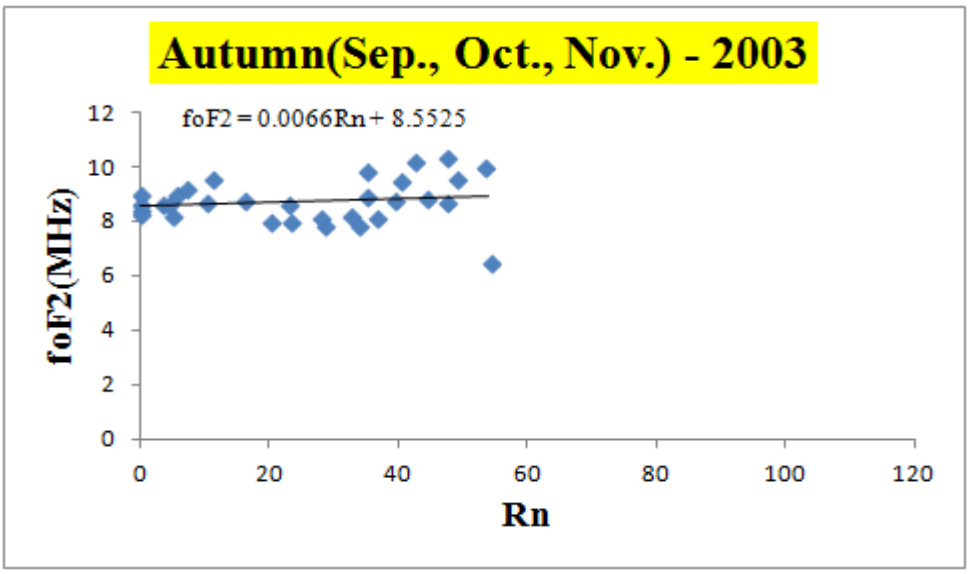

Figure 8- Daily average values of foF2 versus daily average values of Rn at 12 UT during Autumn of 2003.

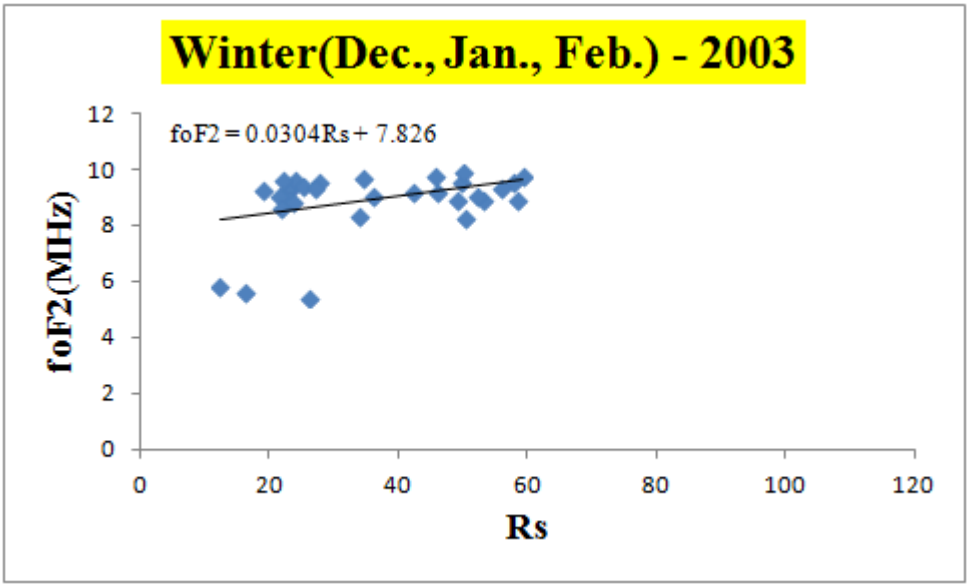

Figure 9- Daily average values of foF2 versus daily average values of Rs at 12 UT during Winter of 2003.

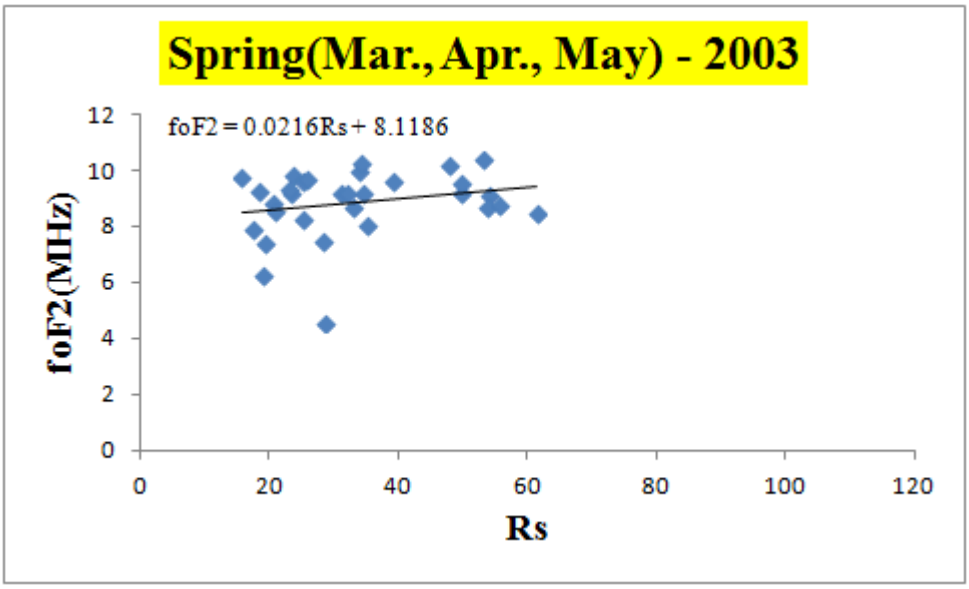

Figure 10- Daily average values of foF2 versus daily average values of Rs at 12 UT during Spring of 2003.

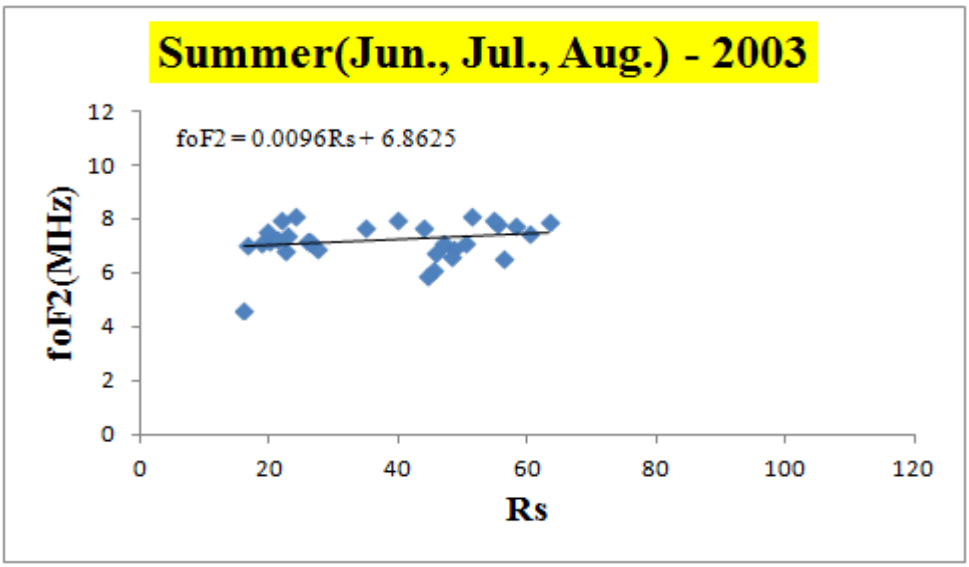

Figure 11- Daily average values of foF2 versus daily average values of Rs at 12 UT during Summer of 2003.

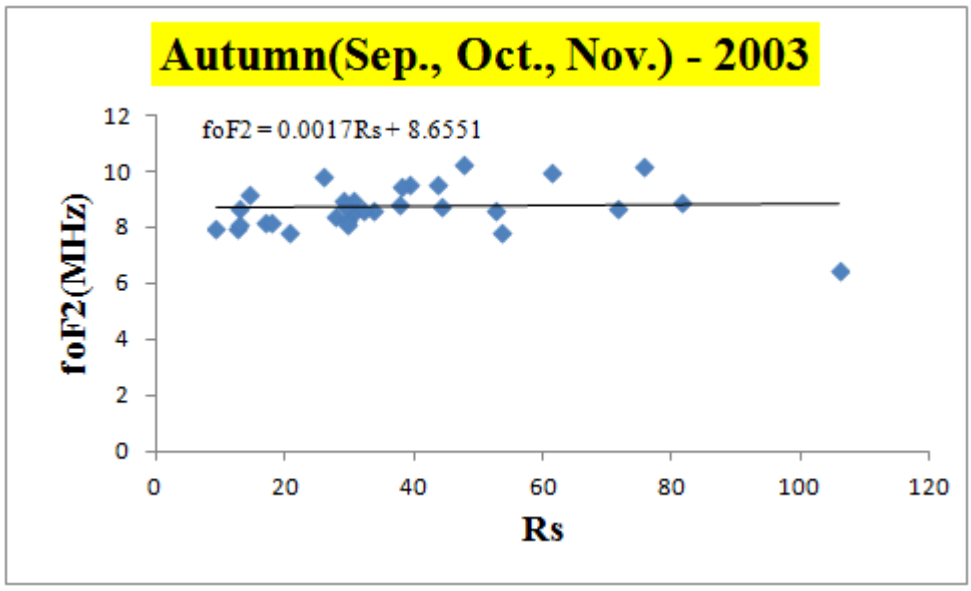

Figure 12- Daily average values of foF2 versus daily average values of Rs at 12 UT during Autumn of 2003.

And the straight line equations for the relationship between foF2 and Ri, were:

foF2 = 0.0647 Ri + 5.298 …….. (1) Winter

foF2 = 0.0231 Ri + 7.4974 …… (2) Spring

foF2 = 0.0209 Ri + 5.6078 …… (3) Summer

foF2 = 0.0024 Ri + 8.5702 …… (4) Autumn

And for the relationship between foF2 and Rn, were:

foF2 = 0.031 Rn + 8.2918 …… (5) Winter

foF2 = 0.0506 Rn + 7.5858 …….. (6) Spring

foF2 = 0.0084 Rn + 6.8837 …….. (7) Summer

foF2 = 0.0066 Rn + 8.5525 …….. (8) Autumn

Whereas for the relationship between foF2 and Rs, were:

foF2 = 0.0304 Rs + 7.826 …… (9) Winter

foF2 = 0.0216 Rs + 8.1186 ……. (10) Spring

foF2 = 0.0096 Rs + 6.8625 ……. (11) Summer

foF2 = 0.0017 Rs + 8.6551 ……. (12) Autumn

Tables (5-7) illustrate the correlation coefficients (a) between foF2 and Ri, Rn and Rs and, also, the intersection points (b) with Y- axis.

Table 5- Correlation coefficients between foF2 and Ri, and intersection points at 12 UT for different seasons of 2003

Seasons	Correlation coefficients (a)	intersection points (b)
Winter	0.0647	5.298
Spring	0.0231	7.4974
Summer	0.0209	5.6078
Autumn	0.0024	8.5702

Table 6- Correlation coefficients between foF2 and Rn, and intersection points at 12 UT for different seasons of 2003

Seasons	Correlation coefficients (a)	intersection points (b)
Winter	0.031	8.2918
Spring	0.0506	7.5858
Summer	0.0084	6.8837
Autumn	0.0066	8.5525

Table 7- Correlation coefficients between foF2 and Rs, and intersection points at 12 UT for different seasons of 2003

Seasons	Correlation coefficients (a)	intersection points (b)
Winter	0.0304	7.826
Spring	0.0216	8.1186
Summer	0.0096	6.8625
Autumn	0.0017	8.6551

Conclusions

From comparison between foF2 and Ri, foF2 and Rn, foF2 and Rs for different seasons of 2003, we conclude the following:

1. The presence of strong relationship between foF2 and Ri during Winter and Summer.
2. The presence of strong relationship between foF2 and Rn during Spring and Autumn.
3. The presence of poor relationship between foF2 and Ri, foF2 and Rn, foF2 and Rs during Autumn.
4. The presence of poor relationship between foF2 and Rn during Summer.

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