ELECTRON DENSITY PROFILES

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The electron density at a certain date, time and location, SSN (smoothed sunspot number), and A-index (Geomagnetic index), are often visualized by means of profile graphs. (SSN and A-index will be explained later.) The electron density profile charts used throughout were calculated and generated with PROBLAB PRO-2 propagation prediction software, sometimes with additions by me, ON5AU, for extra information. See **Fig 5.1 & 5.2**. I hope that the graphs and analyses of this episode will give you some idea of the ever-changing electron density and layer heights in terms of time, date, and season.

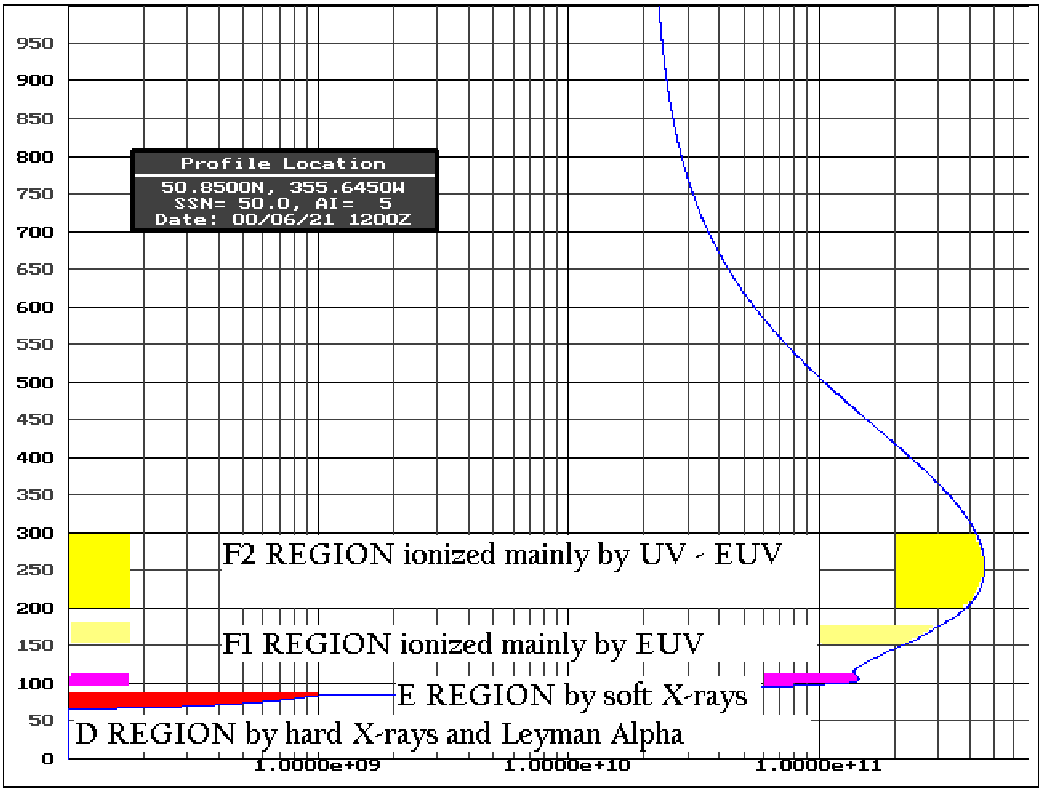


Fig 5.1 *This electron density profile graph was generated at 21 June, midday 12.00 UTC. The additions identify the different ionized regions and the type of radiation that mainly produces them. The horizontal axis is the height in kilometers; the vertical axis the electron density expressed in electrons/cubic meter*

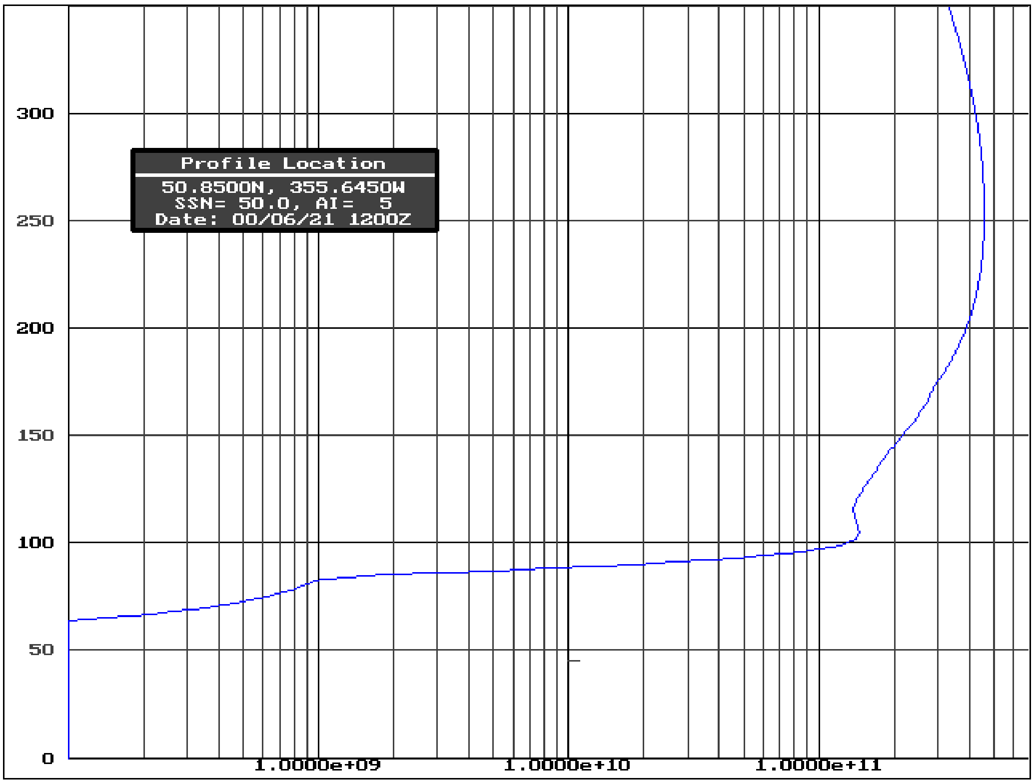


Fig 5.2. *This graph is a magnification of the electron density profile graph shown in fig 5.1 above, but only to a height of 350 kilometer. If you have sharp eyes you can distinguish where the F1-layer starts and ends, from about 145 to 165 km.*

First some explanation about how to interpret the log scale and scientific number notation used with the generated electron density profile graphs. Let's examine **Fig 5.3**.

Log scale explanation.

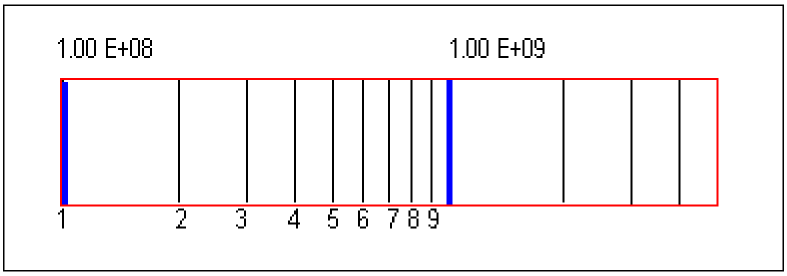


Fig 5.3 *log-scale example. If for instance a value of 4.55 E+08 Is meant, than that point is situated halfway the lines marked with 4 and 5.*

Scientific number notation explanation.

For a positive signed exponent:

4.42 E+11 means	442 000 000 000	E+11 = Multiply by 100 000 000 000.
5.14 E+10 means	51 400 000 000	E+10 = Multiply by 10 000 000 000.
2.29 E+09 means	2 290 000 000	E+09 = Multiply by 1 000 000 000.
9.10 E+08 means	910 000 000	E+08 = Multiply by 100 000 000.

For a negative signed exponent:

6.87 E-08 means 0.000 006 87 E-08 = Multiply by 0.000 000 01
3.41 E-09 means 0.000 000 041 E-09 = Multiply by 0.000 000 001

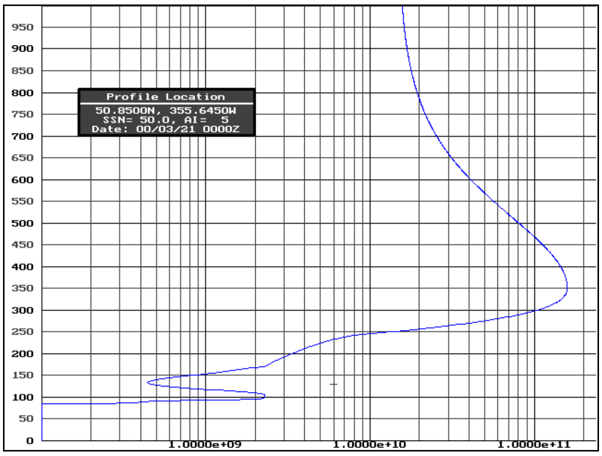
As we noted previously, the ionization grade depends partly on the time of the day. To illustrate this fact, we have generated sixteen examples for the following location: latitude 50.85 N, longitude 4.36 E. This location is Brussels, the capital city of Belgium, which very close to my QTH. I am situated about 35 km (20 miles) west of Brussels. My QTH location is 51.00 N and 3.52 E. The following electron density profile graphs are, respectively, for equinoxes 21 March, 21 September and solstices 21 June, 21 December, the northern hemisphere mid-latitude springtime, autumn, summer, and winter. For each date, I examined four different times--respectively, midnight, midday, sunrise, and sunset. I took 00:00 UTC and 12:00 UTC for midnight and midday, knowing that the time is not exact. Midnight and midday are 16 minutes earlier for longitude 4° East, but the generated results are nearly the same, and the minor differences can be neglected.

With each profile graph, I added some extra data and statements to give you a more complete picture of the situation. For the moment, we may express the F2-layer height as h'F2 in kilometers and express the maximum electron density of three layers in electrons / cubic meter. The numbers are in scientific notation (mantilla plus exponent) to save space when expressing trillions. Note also that the horizontal axis indicating the electron density is a logarithmic scale, in contrast to the vertical axis indicating the height, which is in equal metric divisions.

Examine carefully both the profile graphs and the given numerical data and statements. Try to evaluate the data and make prognoses. Ask yourself some questions and try to answer them before reading the evaluation below. Remember that this data will only give a picture about the mid-northern latitudes. We shall have a chance to look at other locations when we investigate communication circuits around the globe.

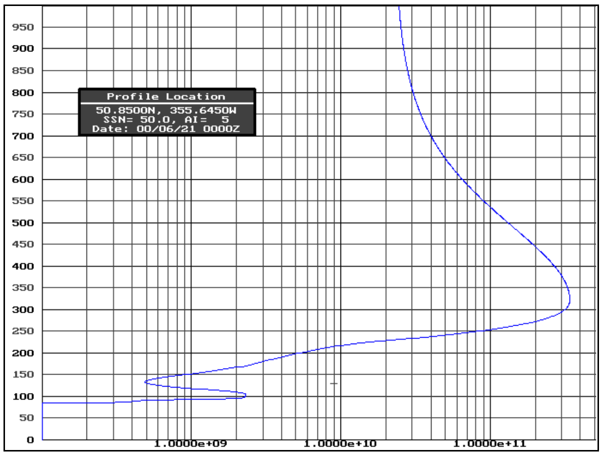
In the following graphs, the height of the diverse layers are denoted as h' D, h' E, h' Es, h' F1 and h' F2, respectively, for the D, E, Es, F1 and F2 layers. The electron density of the diverse layers are denoted as Ne D. Ne E, Ne F1 and Ne F2, respectively, for the D, E, F1 and F2 layers. For these preliminary evaluations, we shall restrict ourselves to the data h' F2, Ne D, Ne E and Ne F2 only.

00:00 UTC= Local Midnight + 15 minutes



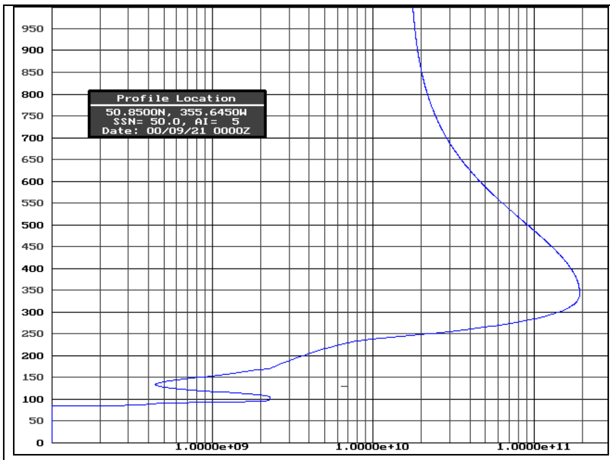
Electron density profile
21 March 00:00 UTC

h'F2	350 km
Max. Ne D	4.00 E+08
Max. Ne E	2.29 E+09
Max. Ne F2	1.58 E+11



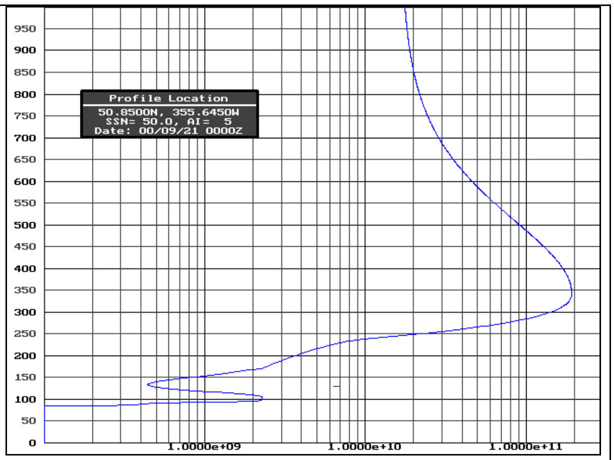
Electron density profile
21 June 00:00 UTC

h'F2	315 km
Max. Ne D	4.00 E+08
Max. Ne E	2.29 E+09
Max. Ne F2	4.03 E+11



Electron density profile
21 September 00:00 UTC

h'F2	343 km.
Max. Ne D	4.00 E+08
Max. Ne E	2.29 E+09
Max. Ne F2	1.92 E+11



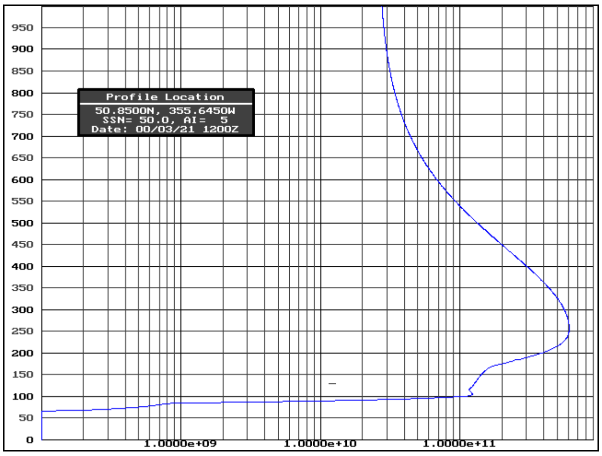
Electron density profile
21 December 00:00 UTC

h'F2	328 km.
Max. Ne D	4.00 E+08
Max. Ne E	2.29 E+09
Max. Ne F2	1.09 E+11

Statements:

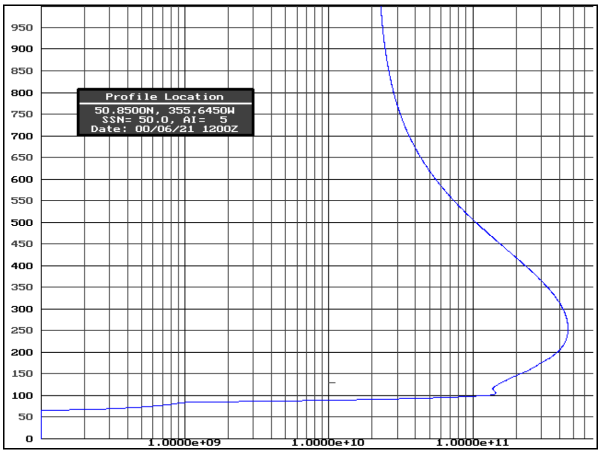
h'F2 highest:	March.
h'F2 lowest:	June.
Ne F2 highest:	June.
Ne F2 lowest:	December.
Average h'F2:	334 km
Average Ne F2:	2.16 E+11

12:00 UTC = Midday + 15 minutes



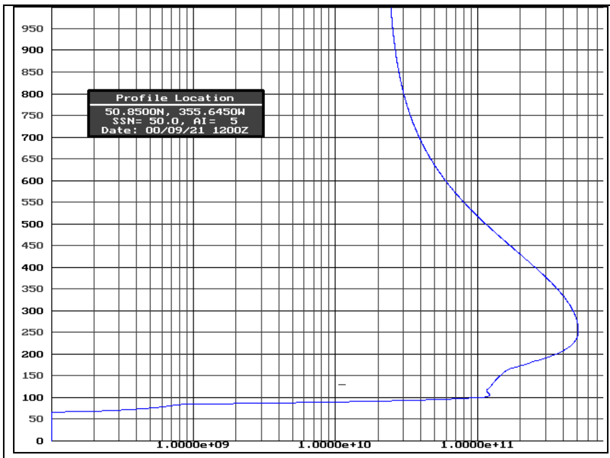
Electron density profile
21 March 12:00 UTC

h'F2	252 km
Max Ne D	7.46 E+08
Max Ne E	1.23 E+11
Max Ne F2	5.97 E+11



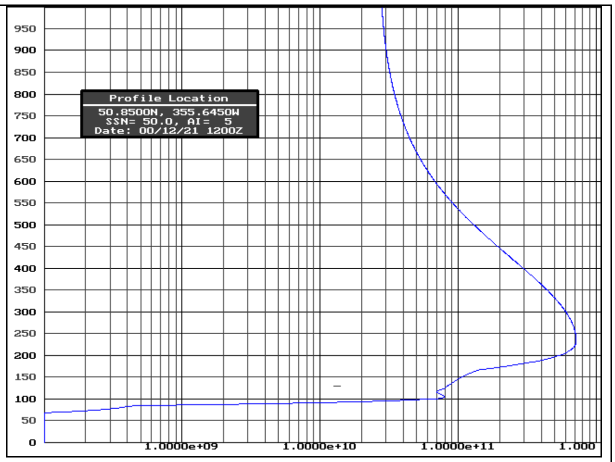
Electron density profile
21 June 12:00 UTC

h'F2	250 km
Max Ne D	9.10 E+08
Max Ne E	1.45 E+11
Max Ne F2	4.42 E+11



Electron density profile
21 September 12:00 UTC

h'F2	250 km
Max Ne D	7.51 E+08
Max Ne E	1.23 E+11
Max Ne F2	5.02 E+11

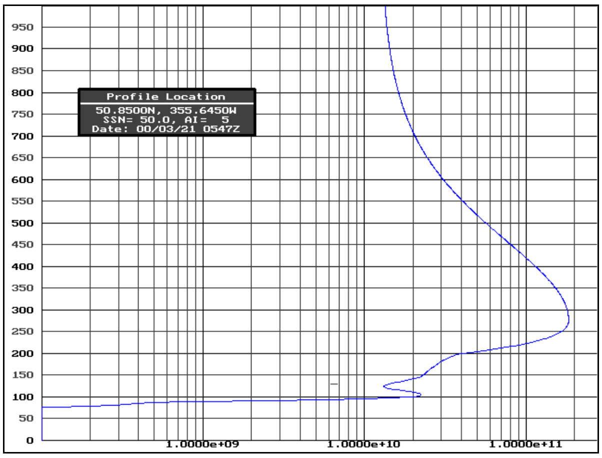


Electron density profile
21 December 12:00 UTC

h'F2	225 km
Max Ne D	4.00 E+08
Max Ne E	8.12 E+09
Max Ne F2	6.90 E+11

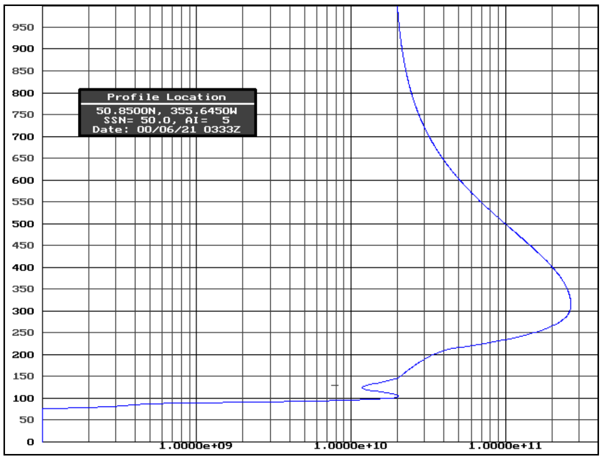
Statements:
h'F2 highest: March.
h'F2 lowest: December.
Ne F2 highest: December.
Ne F2 lowest: June.
Average h'F2: 244 km.
Average Ne F2: 5.57 E+11
h'F2 exceptional stable.
Peak Ne F2 December
Peak Ne D June

Local Sunrise.



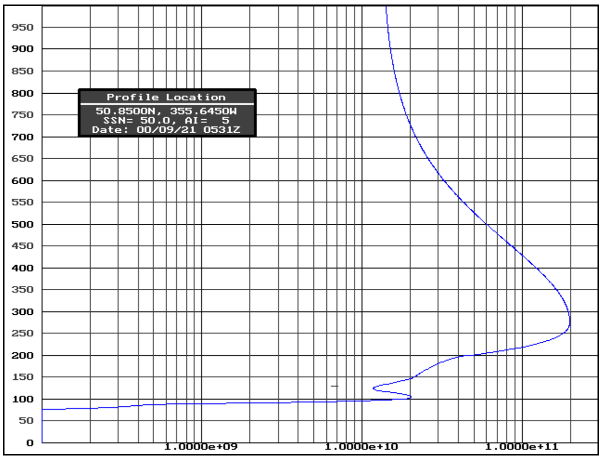
Electron density profile
21 March 05:47 UTC

h'F2	276 km
Max Ne D	4.00 E+08
Max Ne E	2.24 E+10
Max Ne F2	1.84 E+11



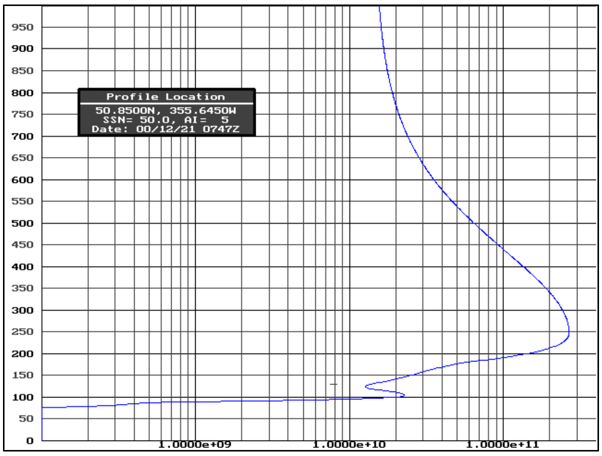
Electron density profile
21 June 03:33 UTC

h'F2	330 km
Max Ne D	4.00 E+08
Max Ne E	2.76 E+09
Max Ne F2	2.68 E+11



Electron density profile
21 September 05:31 UTC

h'F2	275 km
Max Ne D	4.00 E+08
Max Ne E	2.03 E+10
Max Ne F2	1.98 E+11



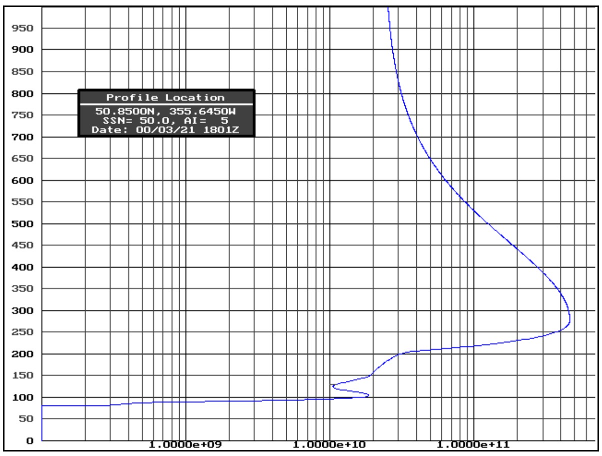
Electron density profile
21 December 07:47 UTC

h'F2	247 km
max Ne D	4.00 E+08
Max Ne E	2.27 E+10
Max Ne F2	2.66 E+11

Statements:

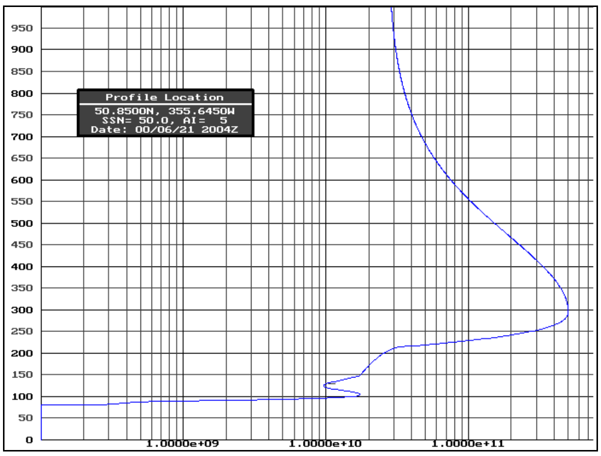
h'F2 highest: June.
h'F2 lowest: December.
Ne F2 highest: June.
Ne F2 lowest: March.
Average h'F2: 282 km.
Average Ne F2: 2.29 E+11
Ne F2 rather stable.
Ne E rather stable.

Local Sunset



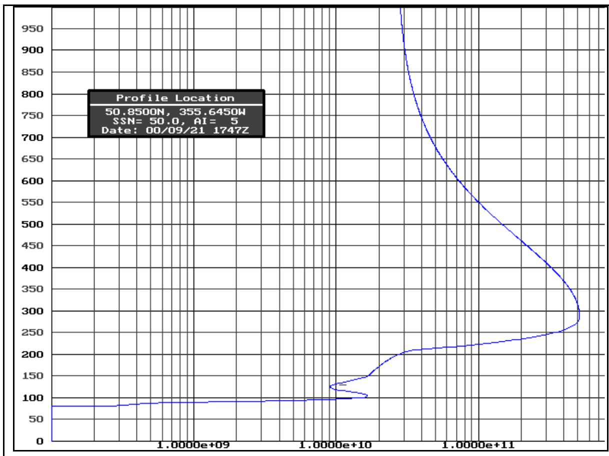
Electron density profile
21 March 18:01 UTC

h'F2	263 km
Max Ne D	4.00 E+08
Max Ne E	5.73 E+10
Max Ne F2	5.81 E+11



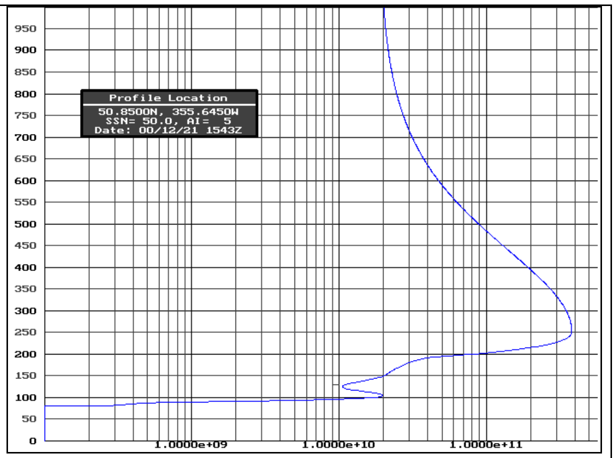
Electron density profile
21 June 20:04 UTC

h'F2	283 km
Max Ne D	4.00 E+08
Max Ne E	4.69 E+10
Max Ne F2	5.08 E+11



Electron density profile
21 September 17:47 UTC

h'F2	273 km
max Ne D	4.00 E+08
Max Ne E	5.81 E+10
Max Ne F2	5.40 E+11



Electron density profile
21 December 15:43 UTC

h'F2	239 km
Max Ne D	4.00 E+08
Max Ne E	5.14 E+10
Max Ne F2	5.49 E+11

Statements:
h'F2 highest: June.
h'F2 lowest: December.
Ne F2 highest: March.
Ne F2 lowest: June.
Average h'F2: 364.5 km
Average Ne F2: 5.44 E+11
Ne F2 rather stable
Ne E rather stable

Primary evaluation:

The preliminary evaluations that follow are summary samples that we must not take as final. Too little data and information is used to interpret the situation in depth. However, the graphs do show trends. The trends apply only to the Brussels, Belgium, location using SSN 50 and A-index 5. Other locations and parameters will be used in future examples. Remember that the ionosphere and its behavior are ever changing in a complicated, never-ending process.

To have a better summary, let's regroup the statements:

Midnight+15 minutes	**Midday+15 minutes**	**Local Sunrise**	**Local Sunset**
Statements: h'F2 highest: March. h'F2 lowest: June. Ne F2 highest: June. Ne F2lowest: December. Average h'F2: 334 km Average Ne F2: 2.16 E+11	**Statements:** h'F2 highest: March. h'F2lowest: December. Ne F2highest: December. Ne F2 lowest: June. Average h'F2: 244 km. Average Ne F2: 5.57 E+11 h'F2 exceptional stable. Peak Ne F2 December Peak Ne D June	**Statements:** h'F2 highest: June. h'F2lowest: December. Ne F2 highest: June. Ne F2 lowest: March. Average h'F2: 282 km. Ave rage Ne F2: 2.29 E+11 Ne F2 rather stable. Ne E rather stable.	**Statements:** h'F2 highest: June. h'F2lowest: December. Ne F2 highest: March. Ne F2 lowest: June. Average h'F2: 364.5 km Average Ne F2: 5.44 E+11 Ne F2 rather stable Ne E rather stable.

In all probability, before and after midday during all seasons, we have the lowest h'F2 (F2-layer height) with the highest Ne F2 (electron density). This fact implies that, over a broad area in the vicinity of the sample location, that period of the day will be good for high frequency use (higher MUF), due to the high Ne values. But the reach of one hop communication will be shorter due to the lower h'F2 height. (MUF and hop communication will be explained in detail later).

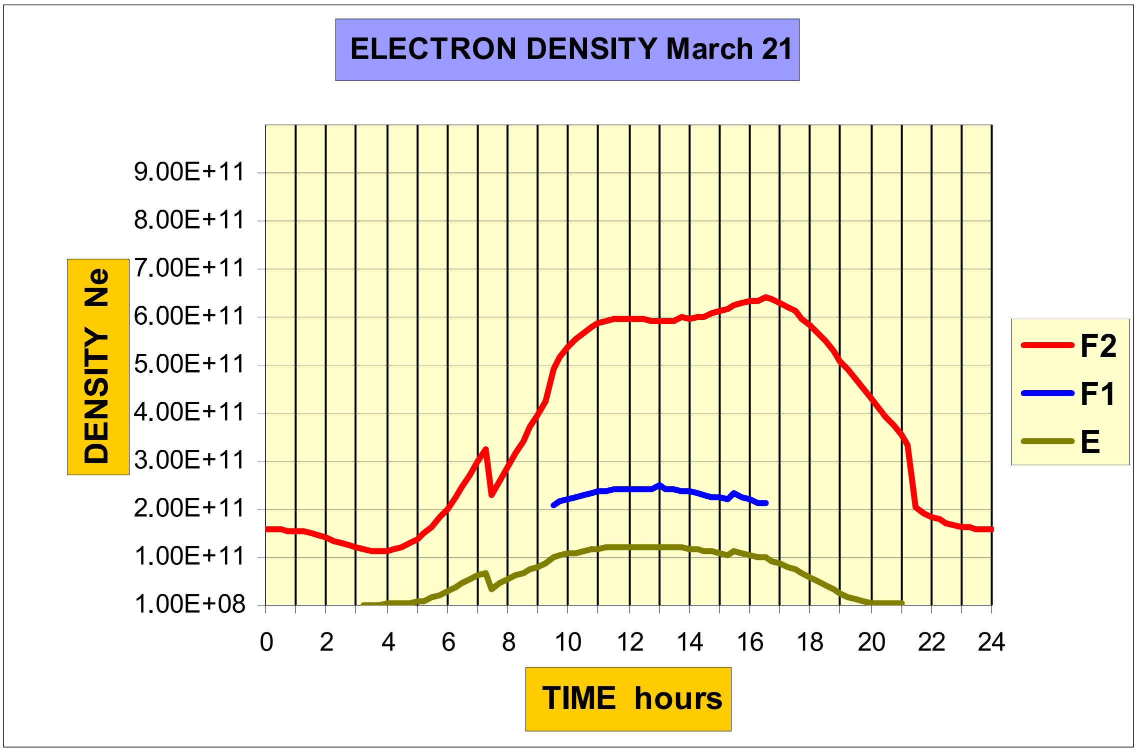
The h'F2 is usually the lowest in December, except during nighttime. However, if we compare the December nighttime h'F2 value (328 km) with the computed h'F2 values for March (350 km), June (315 km), and September (343 km), we may conclude that during the northern hemisphere winter solstice, the F2-layer is situated at the lowest height for both day and night (24 hours).

Further we notice a stable h'F2 height during the whole year at midday, about ± 250 km. This time of stable h'F2 height extends for a period before and after noontime. Only during the northern hemisphere winter solstice time do we notice a slight height decrease.

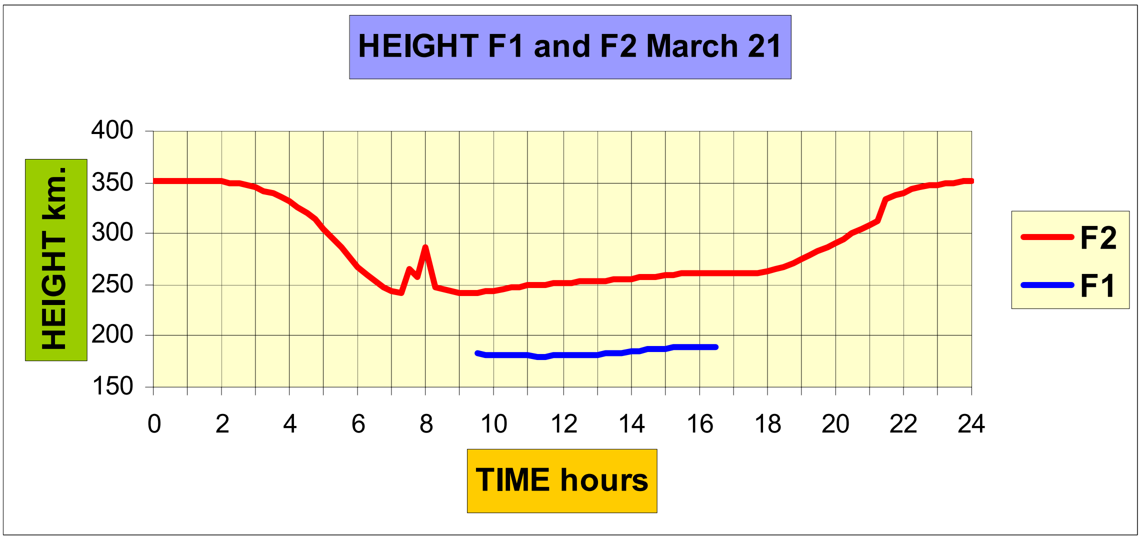
From midday, and in all probability for some hours before, we notice a stable and high Ne F2 density extending towards sunset and probably afterwards. We also notice a high Ne E at midday and a prolonged high Ne E during the afternoon, at least until sunset. During nighttime or dark hours we have the lowest Ne E values. A peak of Ne D exists in June (northern hemisphere summer) at midday. All the probability, these summary statements are too vague and call for further investigation. This investigation will be our next task.

ELECTRON DENSITY and LAYER HEIGHT GRAPHS

For the four seasons, I computed the Ne for the E- F1 and F2 layers and also the h'F1 and h'F2. The h'E is fixed in the computer models at a height of 105 km. In reality, the E-layer height varies little, only a few kilometers, and its role is therefore not too important. (**Note**: Everything is computed for the location **N 50.85 E 4.36**).

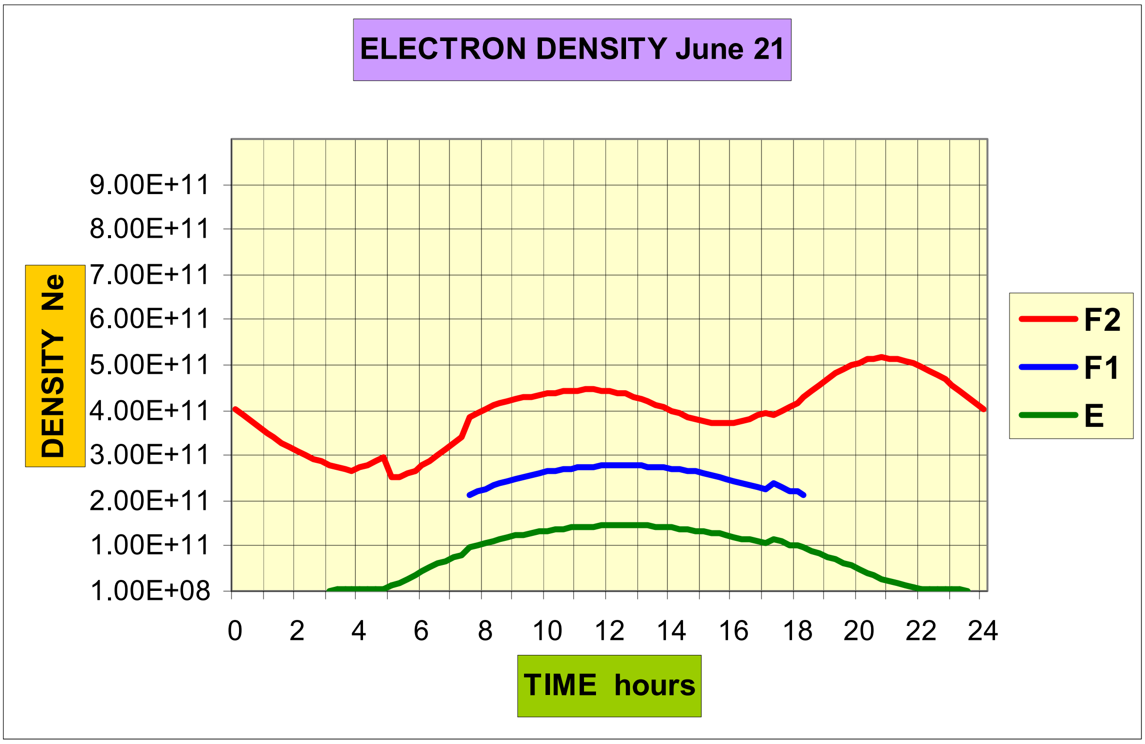


Graph 5.1a. *March 21, electron density F2- F1- and E-layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 5:47. Sunset at 18:01.   Local noon at 11:45.   All UTC.

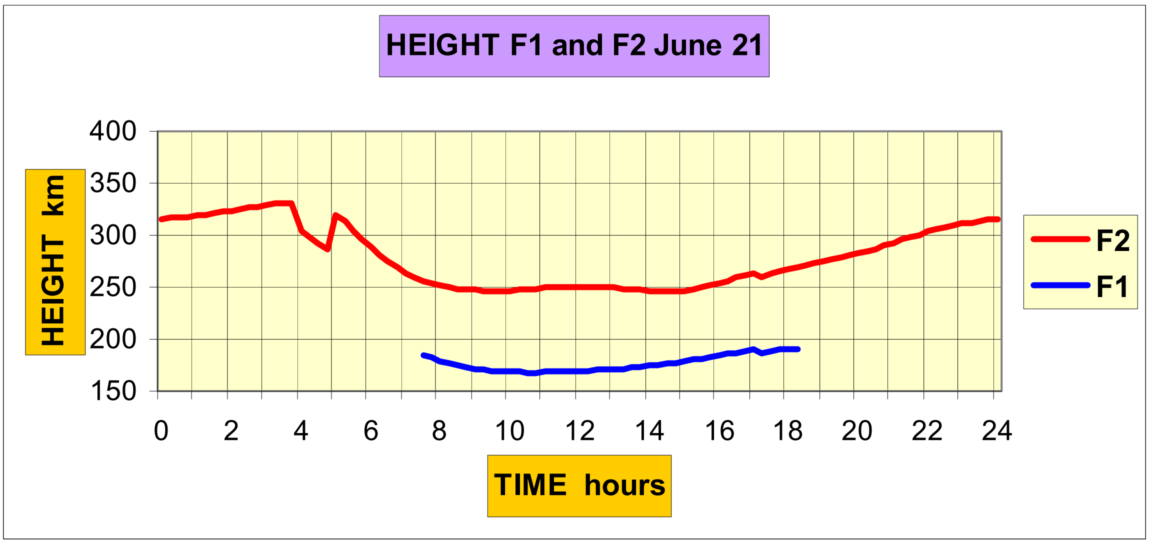


Graph 5.1b. *March 21, height F2 and F1 layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 5:47. Sunset at 18:01.   Local noon at 11:45.   All UTC.

Indications:
NeF2: About one hour after sunrise, notice a sudden odd small decrease and increase and thereafter, a steady climb to a much higher daytime level.
NeE: We find the same unstable phenomenon one hour after sunrise. The layer starts building up from sunrise, reaches the highest electron density at local noon, and thereafter decreases to a low level extending about one hour after sunset.
h'F2: After the unstable NeF2 period, we notice a "nervous" (variable) F2-layer height, followed thereafter by a steady layer height until sunset.
F1: The layer needs some time after sunrise to develop. The Ne F1 increases toward noontime, after which it is slowly decreases. The time of existence before noon is much shorter than after noon.

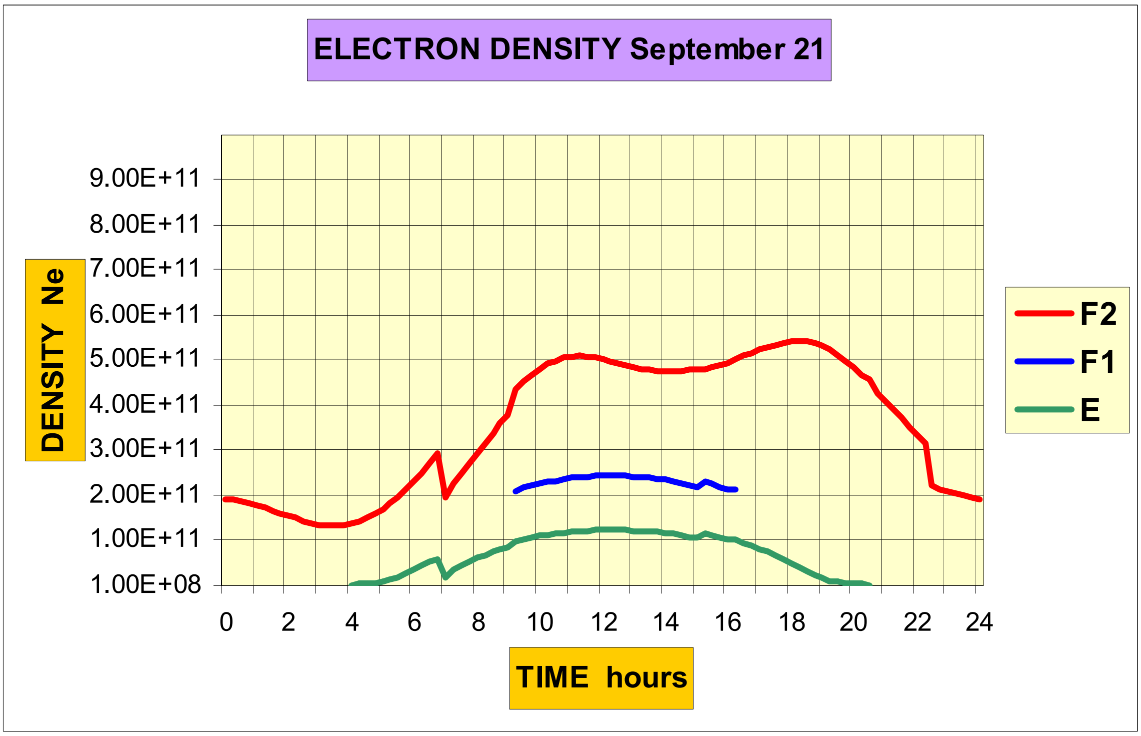


Graph 5.2a. *June 21, electron density F2- F1- and E-layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 3:33. Sunset at 20:04. Local noon at 11:45. All UTC.

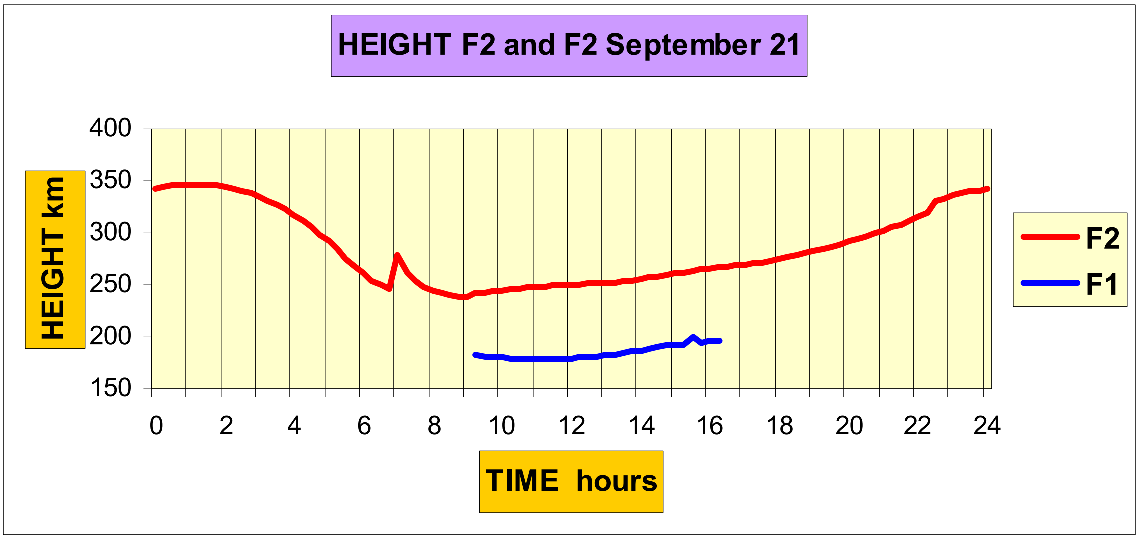


Graph 5.2b. *June 21, height F2 and F1 layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 3:33. Sunset at 20:04.   Local noon at 11:45.   All UTC.

Indications:
NeF2: Shortly after sunrise we see the small decrease and increase of the NeF2. Thereafter we find a steady climb to a higher daytime level. The density curve is much flatter than found for March 21 and the maximum density level reached is much lower, too. Notice that it is best to distinguish two high level peaks, one before noon and one about sunset time, with a dip after noontime. The daytime anomaly is also noticeable here.
NeE: The value increases after sunrise progressing towards the noontime maximum density level. Thereafter the value decreases toward sunset.
h'F2: We find a nervous F2-layer height during sunrise time, after which the layer height slowly decreases to a steady value. The h'F2 increases again from mid-afternoon toward nighttime in a slow and fluent progression and reaches its highest altitude shortly before sunrise.
F1: We find the same properties as we found for March 21, but the layer existence time is logically longer due to the longer daytime hours.

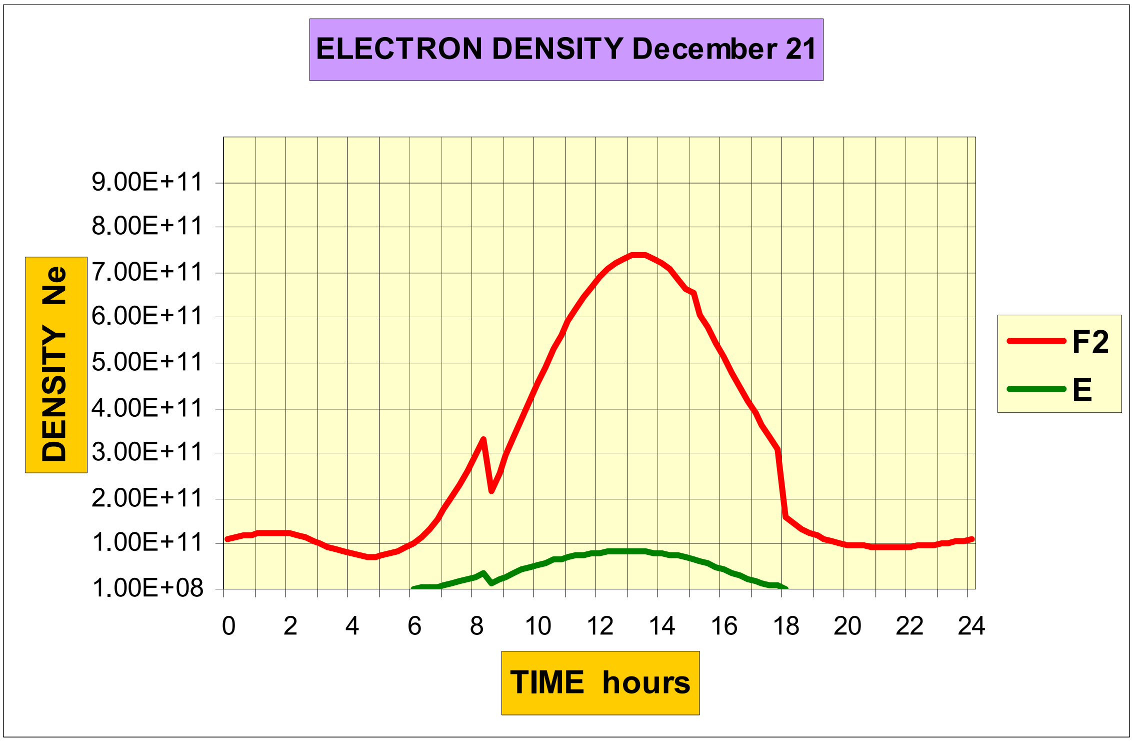


Graph 5.3a. *September 21, electron density F2- F1- and E-layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 5:31. Sunset at 17:47.   Local noon at 11:45.   All UTC.

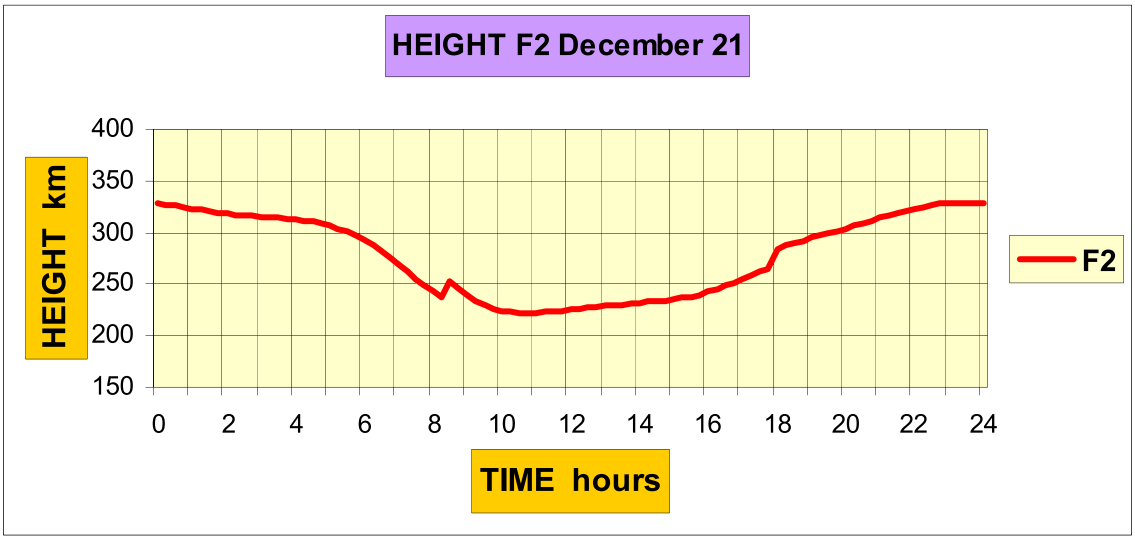


Graph 5.3b. *September 21, height F2 and F1 layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 5:31. Sunset at 17:47. Local noon at 11:45. All UTC.

Indications:
NeF2: The NeF2 behavior shortly after sunrise is very similar to the behavior on March 21. During the daytime, we find one main difference: the maximum NeF2 daytime levels are remarkably lower at September equinox.
NeE: We see the same properties as on the March 21 equinox.
h'F2: The curve is practically the same as on March 21; only the height increases much more steeply after sunset toward the night maximum altitude position.
F1: The values are similar to those of the March 21 period.



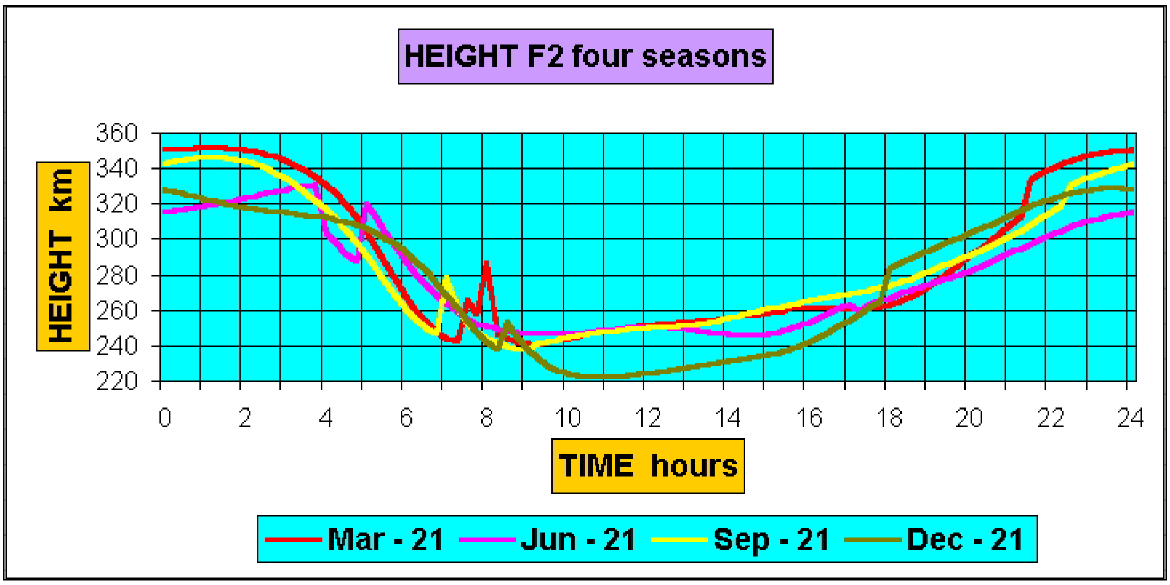
Graph 5.4a. *December 21, electron density F2- and E-layers.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 7:47. Sunset at 15:43. Local noon at 11:45. All UTC.



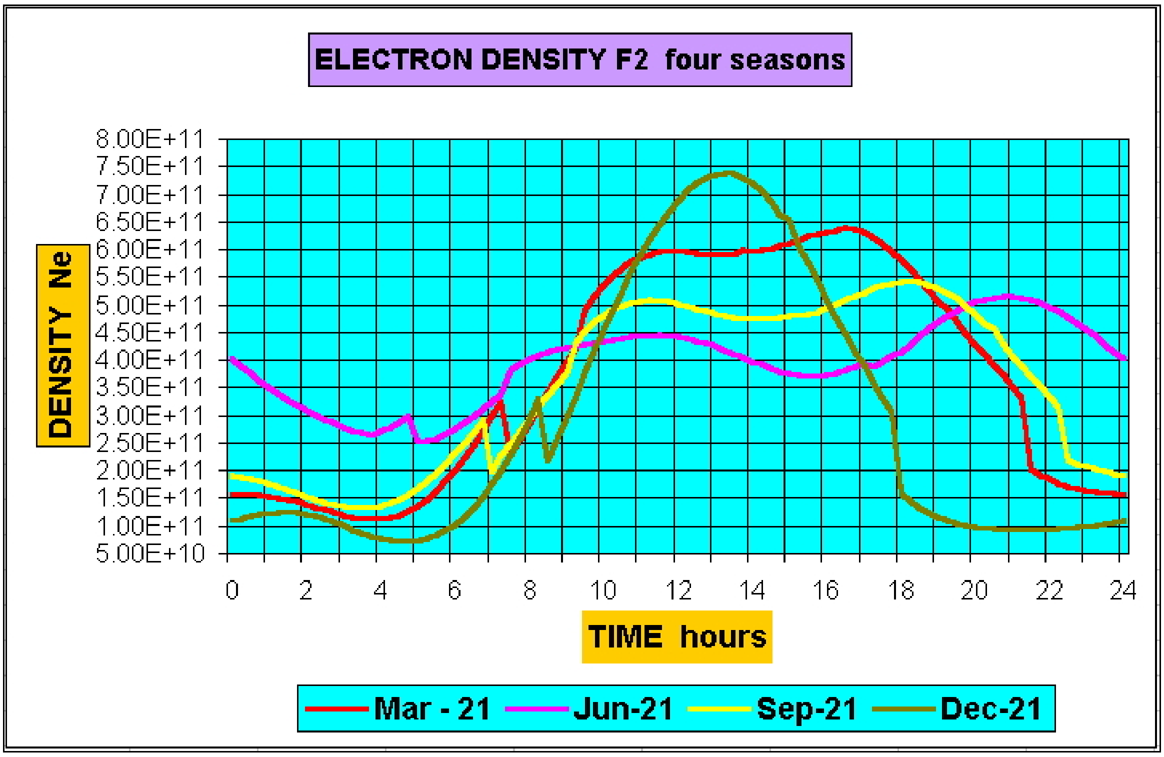
Graph 5.4b. *December 21, height F2 layer.*
SSN 50 - A-index 5 - location 50.85N 4.36E.
Sunrise at 7:47. Sunset at 15:43. Local noon at 11:45. All UTC.

Indications:
NeF2: Short after sunrise, we find the nervous variation of NeF2. An eye catcher here is the high NeF2 level at and around midday. Much higher density levels are reached in this period than in the other seasons. However, the time period of that higher density level is much shorter due to the shorter daytime hours.
NeE: Values are the lowest in this season, since the daytime hours are too short for a large increase.
H'F2: Compared with the forgoing seasons, the height at the lowest level during northern hemisphere winter.
F1: This layer does not exist at mid-northern hemisphere solstice time.

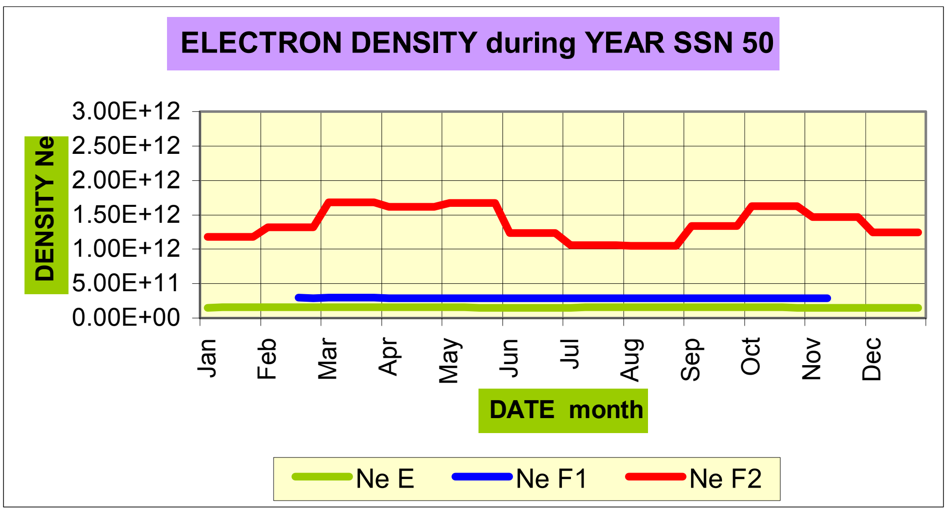
The following two graphs allow us to better visualize the above four-season differences of F2 layer heights and F2 electron density levels. Thereafter, another four graphs will give you an idea of what the computer models tell us. The first two graphs of that series are the monthly values of electron density, E- F1- and F2-layers with SSN 50 and SSN 150, during a year. Finally with the same SSN data, we have two graphs showing the F1 and F2 layer heights (h'F1 and h'F2). The model time is 12:00 UTC.



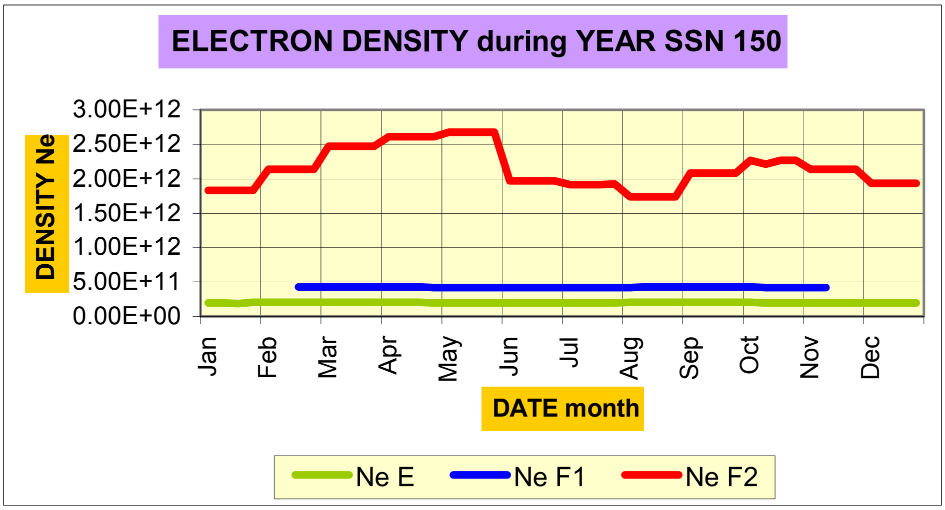
Graph 5.5a. *Height - (h' F2) layer, 21 March, 21 June, 21 September, 21 December.*
SSN 50 - A-index 5 - location 50.85N 4.36E.



Graph 5.5b. *Density - (Ne F2) layer, 21 March, 21 June, 21 September, 21 December.*
SSN 50 - A-index 5 - location 50.85N 4.36E.



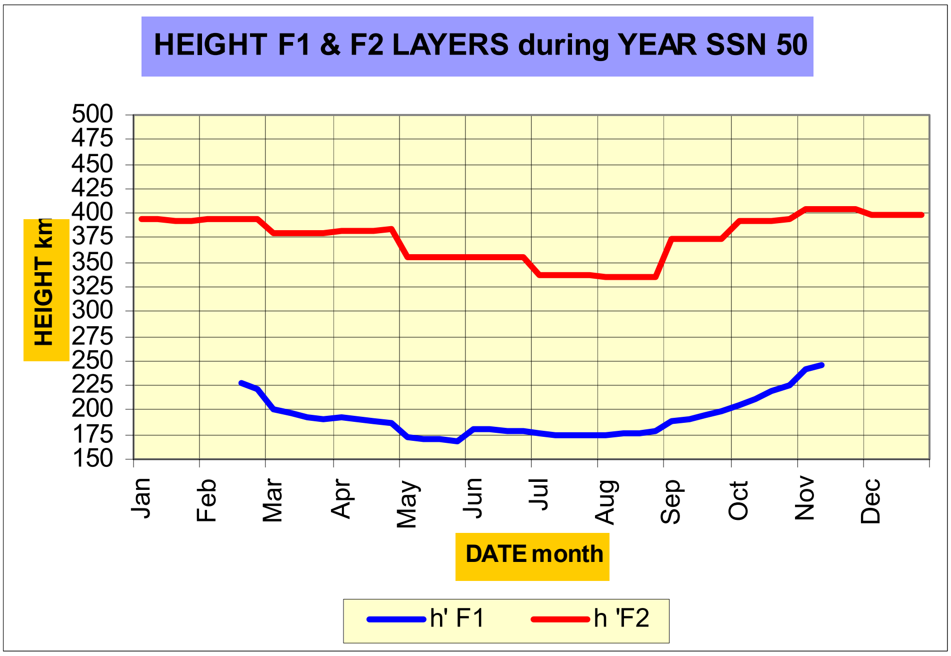
Graph 5.6a *Electron density values of the E- F1 and F2 layers during a year with SSN 50 and A-index 5 at 12:00 UTC, location Brussels (Belgium).*



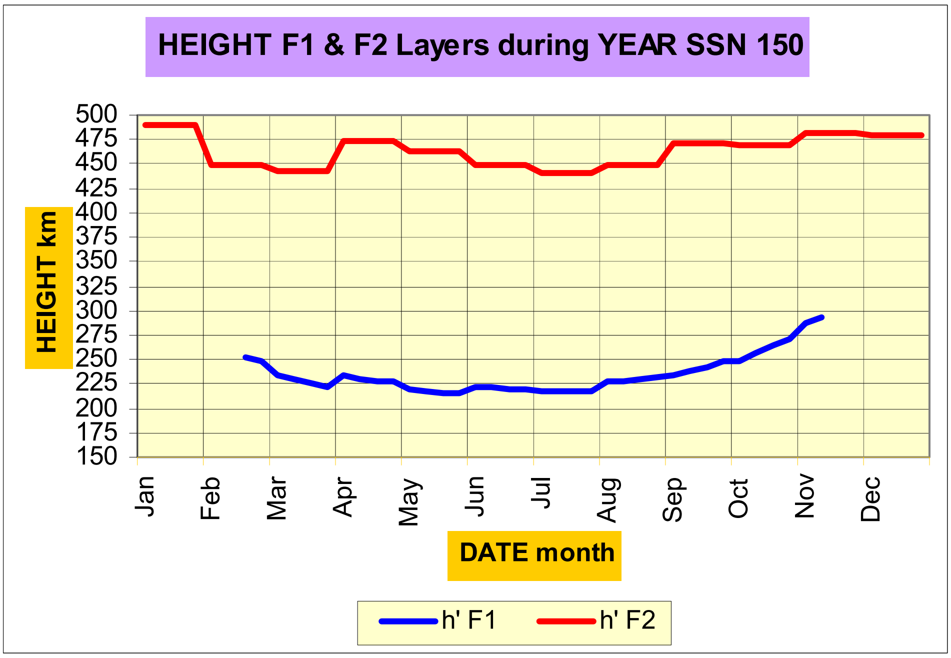
Graph 5.6b *Electron density values of the E- F1 and F2 layers during a year with SSN 150 and A-index 5 at 12:00 UTC, location Brussels (Belgium).*

Graphs 5.6a and 5.6b where computed with data from the software program PROPLAB PRO-2. Later we will also present graphs computed with non-computer modeled values, using values derived from hourly and daily ionograms of real data. When we examine the data from reality, we shall be able to evaluate the credibility of propagation prediction software programs. In those future graphs, we shall also present much more data about miscellaneous ionosphere phenomena and properties that are still to be explained. Also note: the graphs that we have so far examined apply only to a given location (a normal mid latitude). Locations such as equatorial, polar or other regions can and often do give you quit different properties and phenomena. These locations and their differences will show up in future issues.

Note: Ionograms will be handled in depth in a forthcoming part.



Graph 5.6a *Height of F1and F2 layers during a year with SSN 50 and A-index 5 at 12:00 UTC, location Brussels (Belgium).*



Graph 5.7b *Height of F1and F2 layers during a year with SSN 150 and A-index 5 at 12:00 UTC, location Brussels (Belgium).*

For the moment, I hope that the graphs and analyses of this episode give some idea of the ever-changing electron density and layer heights in terms of time, date, and season. Examine closely at the electron density graphs and try to discover some anomalies that we shall mention in the forthcoming issues. The subjects that we explored here will return in later episodes, but the time has now come to investigate the next important ionospheric element.

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