SOLAR TERRESTRIAL DISPATCH

Software for Science

Proplab-Pro Version 3

SOFTWARE FOR SCIENCE

Proplab-Pro Users Guide

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Installation / Introduction

Simple and quick.

Congratulations on your purchase of Proplab-Pro Version 3! If you're reading this, you have successfully installed Proplab-Pro Version 3, the most advanced radio propagation ray-tracing system in the world!

Proplab-Pro Version 3 is a state-of-the-art software package not for the feint of heart. A basic understanding of radio propagation and terms related to radio propagation is presumed. If you don't know what the F-region is, or think the ionosphere is flat, you had better grab yourself a holiday at the library before proceeding further. To help, we have included a copy of the user's manual for Version 2, not because it applies in any specific way to the operation of Version 3 (it doesn't), but because it has a very nice introduction to radio propagation and ray theory. Many of the features in Version 3 are not available in Version 2, and there may even be a few things that were present in Version 2 that are not present in Version 3, such as the DOS screen. If anyone can spot a feature that is missing from this latest version, by all means let us know. We would love nothing more than to debug something else! Seriously?

To save space, sanity, and eye-wear, we will henceforth refer to Proplab-Pro Version 3 as simply Proplab. If we need to refer to the archaic Version 2 of Proplab, which is now soundly and respectably forming oil deposits somewhere in the Earth's crust, we will specifically name it.

It's now time to put on your hard hat and start having some fun.

Quick Start

...for the impatient...

If you're the impatient type who does not like to read through pages and pages of incomprehensible computer instructions describing how something you purchased works, feel free to throw this away and start using Proplab blindly. It is probably simple enough to figure out on your own. Use this document as a doorstop in that case (*after* you print it out, of course!).

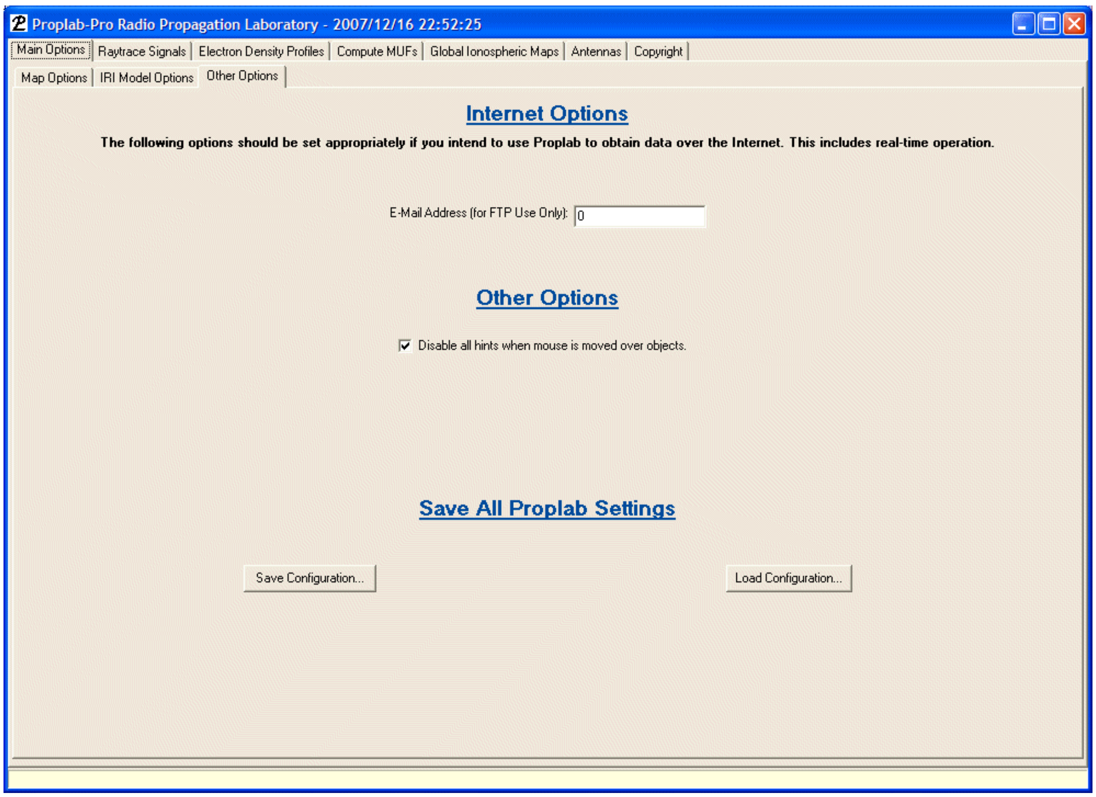
For the impatient, run Proplab and fill in your e-mail address on the first screen. Also make sure that the only checkbox on that page is left UN-checked, unless you're a genius, in which case we have a job opportunity for you!

Sorry we can't show you any helpful screen-shots. Use your imagination.

For those who are slightly less impatient, or for those who'd like some pretty pictures, read on. We aim to please!

Not So Quick Start

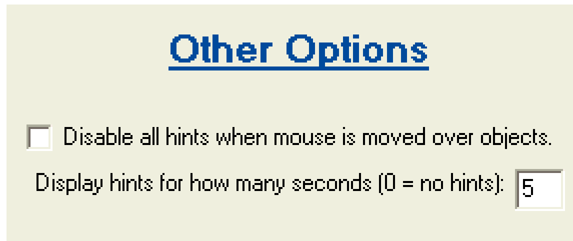
When you first run Proplab, you should see a screen like this (below, or on the next page). If you don't, we probably screwed up the packaging of Proplab – in which case you can find it by clicking on the Main Options tab followed by the Other Options tab.



Without a doubt, this is the single most exciting page we could have shown you! Were it not for its importance, we would have axed it long ago. It is important because without it, you would not be able to obtain information from the Internet to help you operate Proplab, and you would not be able to obtain helping hints as you run it.

You are asked to type in your e-mail address. Please do so. Although a fictitious address would work just as well, it's sort of nice to the owners of the sites where the data is stored if your real e-mail address is used. The only sites that are visited are U.S. government machines (yes, they are public-domain and are free to use) and our own company server (spacew.com); and the only reason your e-mail address is needed is to fulfill the requirements of the anonymous FTP protocol. To avoid the need of spewing out another useless computer acronym, let's just say that without this protocol, Proplab would not be able to use the Internet at all. So it's a little bit important.

Below that lone box is another lonelier checkbox that you may find quite useful to keep UN-checked.



When the "Disable all hints…" checkbox is unchecked, your mouse will become your friend and will display hints of help if you hold it over a control that you don't quite understand. The hint will be displayed for a few seconds and then disappear. The length of time the hint is displayed can be controlled in the bottom box. Use it until you become accustomed to the features of the software.

After a while, once you know your way around Proplab and are able to use its features blindfolded, this checkbox will become your "sanity savior." By un-checking this box, all of those nice helpful hints will stop appearing when you hold your mouse over various controls. You can also specify "0" (zero) in the bottom box to disable the hints.

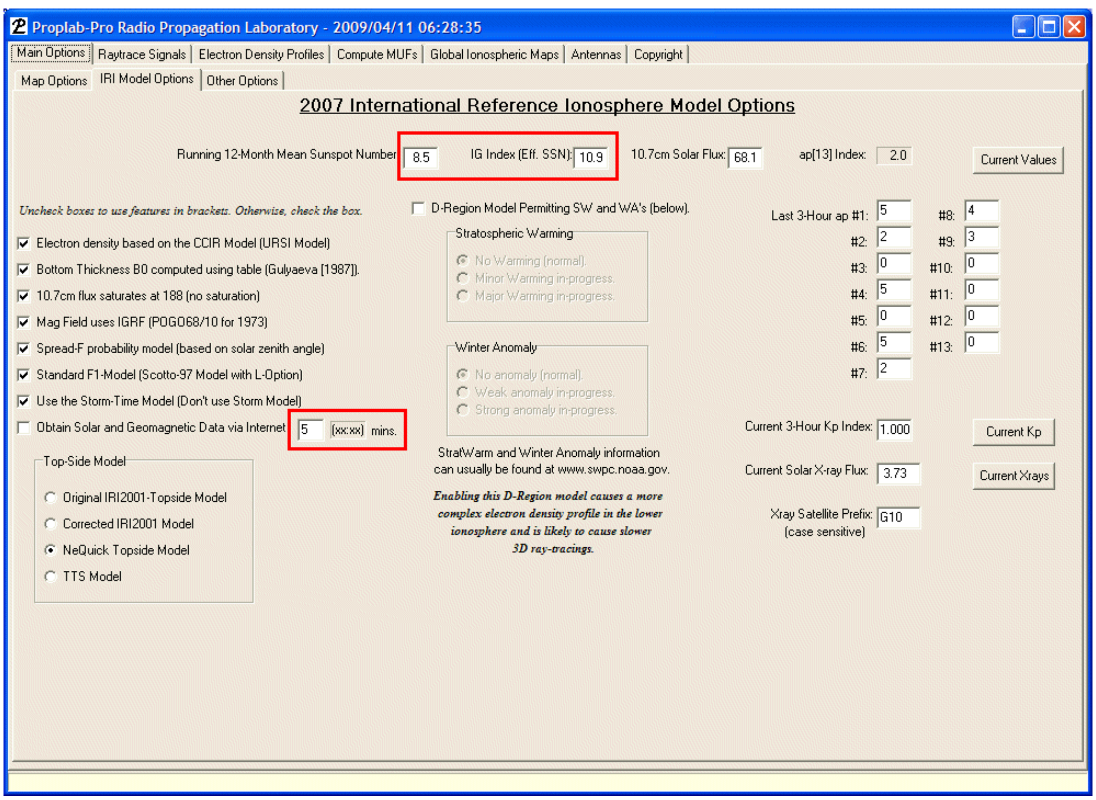
Below the Other Options section are two buttons for loading or saving all of the settings in Proplab. This lets you use more than one profile (for different scenarios, etc).

THE 2007 INTERNATIONAL REFERENCE IONOSPHERE

As you may have heard, Proplab-Pro comes equipped with the 2007 International Reference Ionosphere (also known as the IRI). There have been many different versions of the IRI throughout the years. Every so often, some of the worlds smartest scientists and other intelligent beings get together to help describe the nature of the Earth's ionosphere in mathematical terms. All of the ideas, theories and mathematical innards that form the basis of our understanding of the Earth's ionosphere is then compiled together by the working group whose task it is to create the next International Reference Ionosphere. Their work is then passed onto another small group of equally smart people who know no other language than that spoken by computers. Their job is to make a working set of computer codes that can be used to fully describe the Earth's ionosphere in the best possible terms, using one of the oldest and most archaic computer languages known to man. This is akin to writing a modern masterpiece entirely in Latin. Their completed project is then tactfully named the International Reference Ionosphere and is pre-fixed with the year that their work was completed. At the time of this writing, the latest and greatest version of the IRI was completed in 2007. We have kindly retranslated and integrated that code into Proplab, with only one of our programmers suffering premature aging in the process.

For those without a good grasp, this is truly significant. IRI2007 is, without question, one of the most elaborate and useful versions that the IRI working group has ever produced. It generates more accurate ionospheric electron density profiles than ever before and gives Proplab the ability to ray-trace through even more realistic simulations of the Earth's ionosphere. The end-result is greater accuracy, even during geomagnetically disturbed periods.

The "IRI Model Options" page gives you control over many IRI2007 model features.



For most who read this, an in-depth understanding of exactly what these checkboxes do will be well beyond your need to know. They "simply" turn on or off various models used by the IRI to calculate ionospheric properties that Proplab uses. For a more detailed discussion, do an Internet search for "Ionosphere IRI." There is a heap-load of technical information out there for you to bury yourself in.

The box outlined in red in the lower-left determines how many minutes the system will wait between fetching internet data. You can reset the timer by clicking on the "(xx:xx)" text box.

This screen is also the location where you adjust the various ionospheric input values, such as the sunspot number, the "effective" sunspot number (IG index), the solar flux and the geomagnetic parameters.

Important: Most propagation programs on the market have accepted the sunspot number as an input to adjust the shapes of the ionospheric layers. Fairly recently, improvements were made by correlating observed ionospheric profiles with modeled ones and then adjusting the sunspot number until a closest-fit is observed. This adjusted sunspot number is known as the IG index. Proplab-Pro uses both the international smoothed sunspot number and the IG index to shape the ionospheric layers. If you do not have access to the IG index, you can retrieve the latest value by clicking on the "Current Values" button. If you want to experiment with your own values, set **both** the sunspot number **and** the IG index number (see the upper red box) to the **same** value. Under normal quiet conditions, the sunspot number and the IG index should be very similar. Variations are greatest during geomagnetically disturbed intervals.

The geomagnetic indices are used when the "Use Storm-Time Model" checkbox option is checked. That model enhances the shapes of the ionospheric layers to include the near real-time effects of geomagnetic activity on global electron densities.

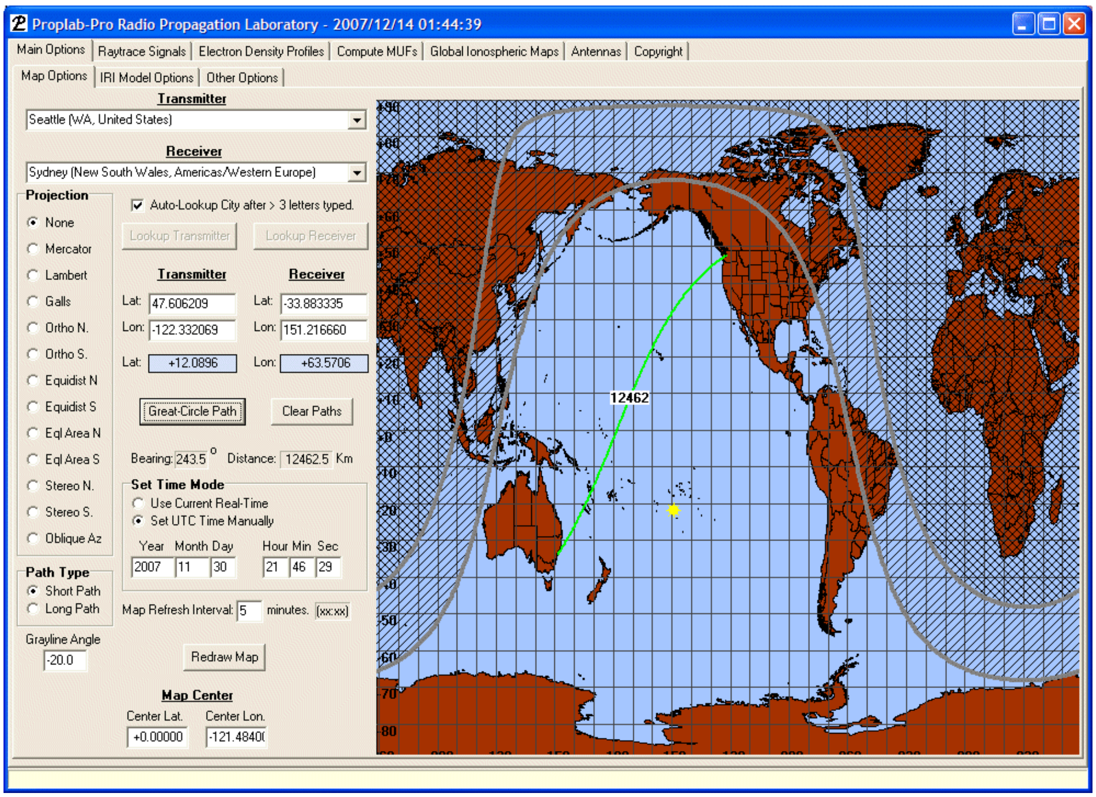
Improvements in layer shapes give greater precision to ray-traced results.

The "Current x-ray solar flux" is an important parameter used in producing global ionospheric maps of radio signal absorption. To obtain the latest x-ray data click on the "Current Xrays" button or the "Current Values" button.

Map Location Settings

The fun starts here!

The main map of Proplab is available by clicking on the Main Options tab followed by the Map Options tab. You will visit this page often, so learn it well.



This page lets you set up everything from the type of map to display to the latitude and longitude of the transmitter and receiver you plan to use for your ray tracing analyses. It also gives you control over many other items which we will briefly cover here.

MAP PROJECTIONS

Proplab will let you draw global or hemispheric maps using up to 13 different kinds of projections from Mercator to Oblique Azimuthal Equidistant and several spherical hemispheric projections. Not all of these map projections can be used in all of Proplab's functions. In some areas, Proplab requires that you use specific cylindrical projections. But the variety of projections available here will let you view your signal path in just about any flavor desired.

SHORT / LONG PATHS

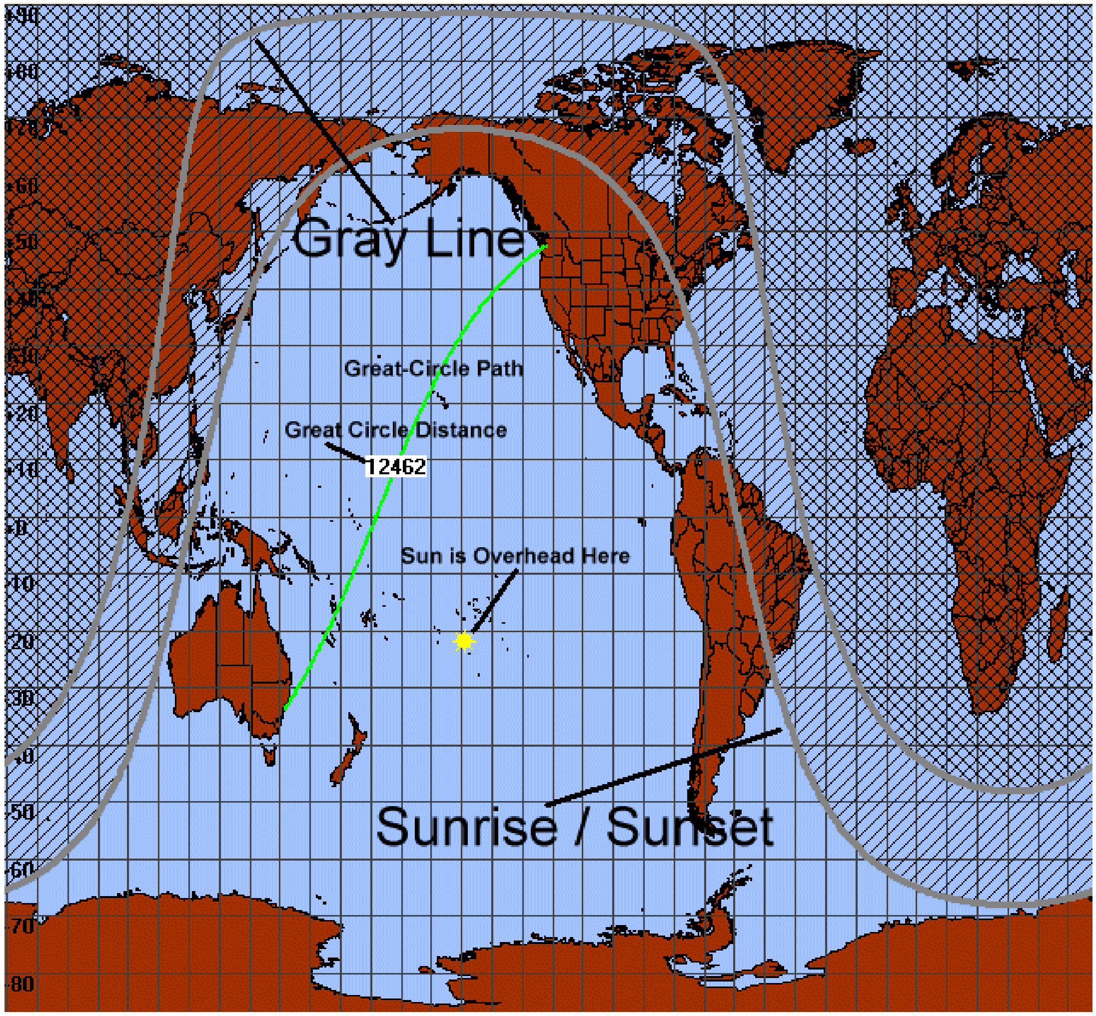
You can also select between short and long great-circle paths. Note that the 3D ray-tracing engine is limited to short-paths only. If you want to examine long-paths, change your transmitter azimuths by 180 degrees and set the distance to ray-trace up to 20,000 km. Yes, there is a 3D ray-tracing limit of 20,000 km (half-way around the world).

GRAY ANGLES

No, this has nothing to do with hair. It has everything to do with sunrise and sunset lines on the Earth. The area of the Earth where the sun is rising or setting forms an area known as the "gray line," supposedly for the area of the Earth that is transitioning from bright (or white) to dark (or black) – the gray region.

A box is available on this page that lets you change the gray angle. In other words, it changes the region that is considered "gray." The angle specifies the line around the earth where the sun is the specified number of degrees **below** the horizon.

A screen shot showing the various features of the map are shown below.



It's pretty simple and straight forward.

Note that **all** distances in Proplab are in kilometers.

You can erase the great-circle path by clicking on the "Clear paths" button.

TRANSMITTER AND RECEIVER LOCATIONS

There are several easy ways in which you can set the transmitter and receiver locations using Proplab's map. The simplest is with your mouse: move your mouse to the location where you want to identify the transmitter and click the LEFT mouse button. This marks the transmitter. To mark the receiver location, move your mouse and click on the RIGHT mouse button. The latitudes and longitudes will be set accordingly. If you want to identify your new locations, you can type in your own city names in the respective boxes (if you do, make sure that you UN-check the "Auto-lookup city" checkbox, otherwise the software will try to find the names you type in the database).

Speaking of databases, Proplab is equipped with one of the largest city databases in the world. You can easily and quickly look up any of the over 5 million city and place names included in the database. You might even find your local high-school or hospital listed!

There are two different ways you can look up cities, depending on whether the "Auto-lookup" checkbox is checked or not. If the checkbox is checked, Proplab will automatically begin searching for the city name you type if the following conditions are met: **a)** you type in a minimum of 3 characters **and** **b)** you wait at least 3 seconds after typing your last character. When these conditions are met, Proplab will automatically search the database for the name (or the name fragment) that you have typed. It will then display the results in a drop-down box. Simply choose the city that matches what you are looking for and click on it. The corresponding city latitude and longitude will then be automatically entered into the appropriate boxes.

The other way to search for cities is only possible when the "Auto-lookup" box is UN-checked. When it is unchecked, type a name into the transmitter or receiver city name box. To search for that name, click on the "Lookup Transmitter" or the "Lookup Receiver" button to begin the search. Then select the proper city from the drop-down box.

CENTERING THE MAPS

Some of the maps – in particular, the Oblique Azimuthal projection – work best if the map is centered on your particular latitude and longitude. To re-center the maps on your particular latitude and longitude, change the settings of the boxes at the base of the map display. Then click on the Redraw Map button.

Electron Density Profile Charts

Real-time (or not), it's a cool feature to play with.

Electron densities are the "be all" and "end all" for radio signal propagation. Radio communications around the world would not be possible without electrons in the ionosphere. They provide the physics that bend radio signals back to the Earth. Without them, the signals would travel in a straight line into space and be forever lost in the emptiness thereof.

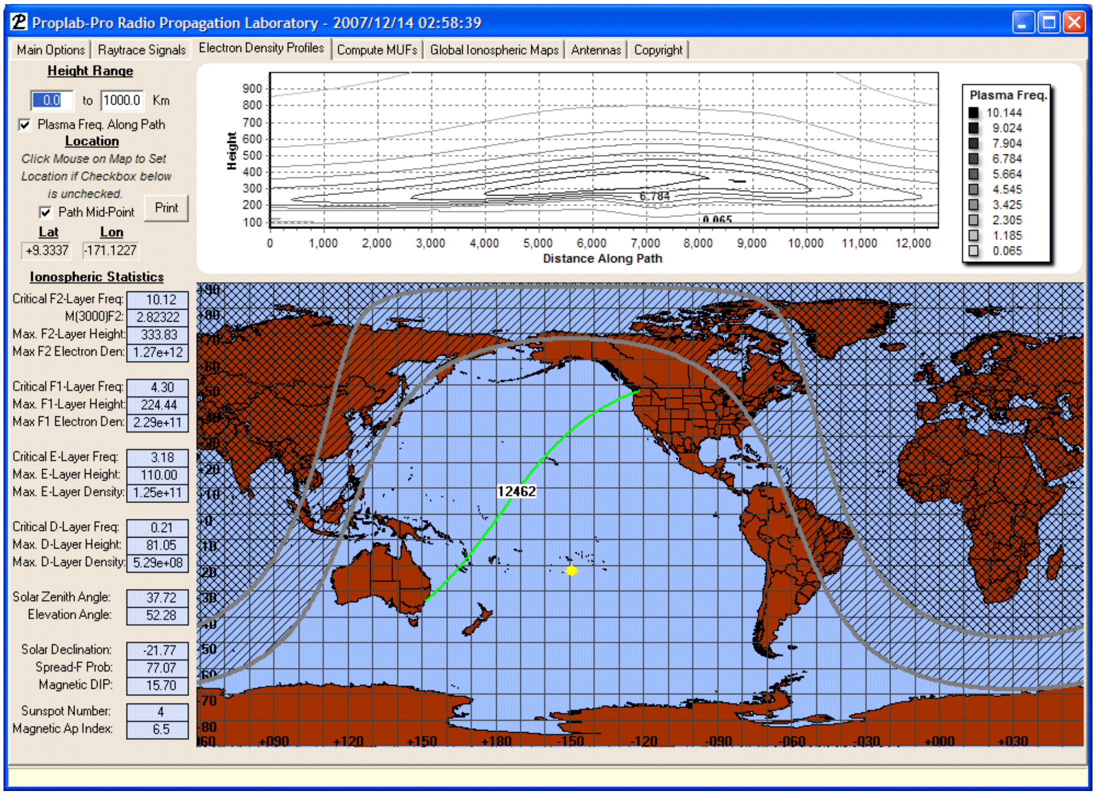
The ability of the ionosphere to bend radio signals depends intricately on the electron density in the ionosphere. If the density is high, radio signals of high frequency can be reflected back to the Earth. If the density is low, only lower frequency signals can be reflected back to the Earth.

A radio signal that is propagated vertically must bend more in order to reach the Earth. As a result, a vertically propagated radio signal needs either a much higher density of electrons or a much lower frequency in order to be bent back towards the Earth. ***The highest frequency that would be completely reflected back to the Earth at vertical incidence is known as the critical frequency. The highest frequency that would be reflected by the F2 region is known as the critical frequency of the F2 layer.*** Any frequency higher than the F2 critical frequency will not (ever) reach the Earth and will be lost to deep space.

This frequency is also known as the plasma frequency.

Proplab is capable of plotting the ionospheric electron density shape for any point over the Earth's surface. It is also capable of looking at the two dimensional shape of the ionospheric layers along any great-circle path, akin to taking a knife along the path and cutting through the ionosphere to look at the layers you have cut into.

In the following discussion, we will use the same great-circle path as was used in the screen-captures for the last chapter. The transmitter is located in Seattle, Washington and the receiver is located in Sydney, Australia.



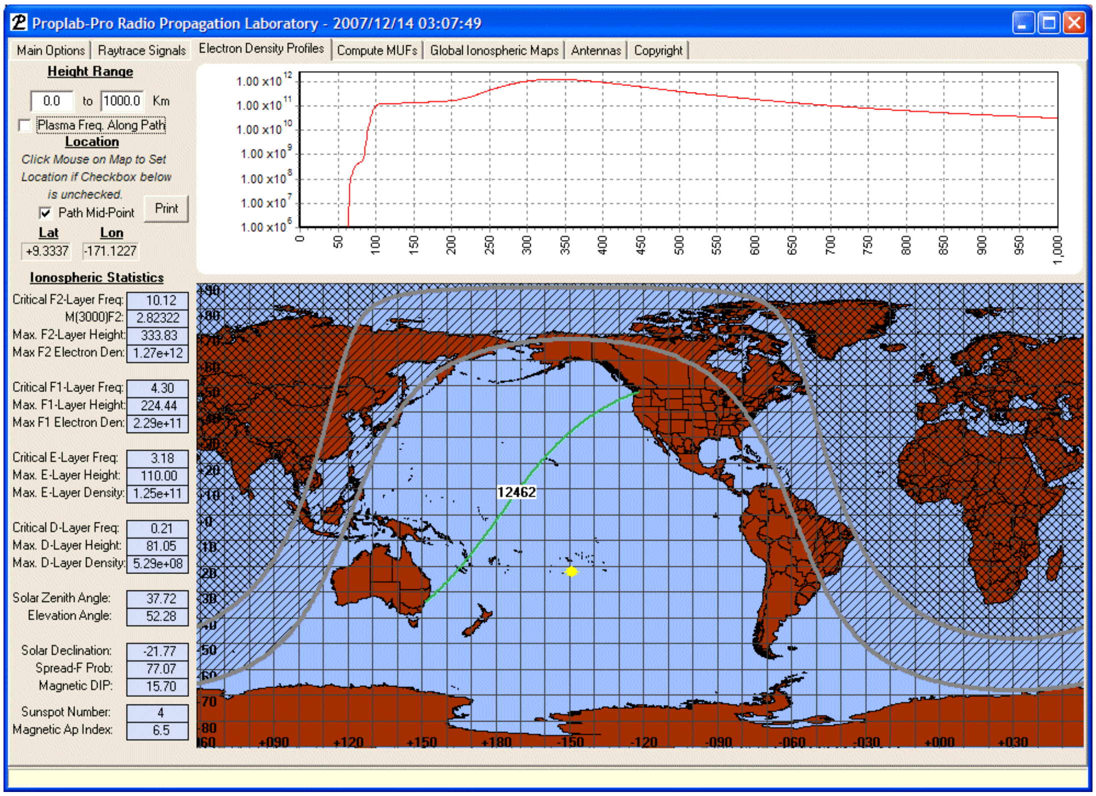
The upper chart shows the plasma frequency contours across the entire great-circle path from Seattle to Sydney. This is particularly useful information to the radio communications specialist because it shows how the ionospheric layers are tilted. Tilts in the ionospheric layers can cause non-great-circle propagation and other odd behavior such as chordal hops, etc. This chart can therefore help you diagnose potential propagation anomalies without requiring any ray-tracing at all.

You can see that the ionospheric layer near the peak critical frequency of the F2-region (around 300 km in height) is tilted, particularly near the midpoint of the path roughly 5,000 to 7,000 km along the path. Rays which are reflected by that region will be refracted differently than a normal spherically ionized layer would.

By searching various paths, you can use this feature to find flatter areas that will produce more stable ionospheric reflections.

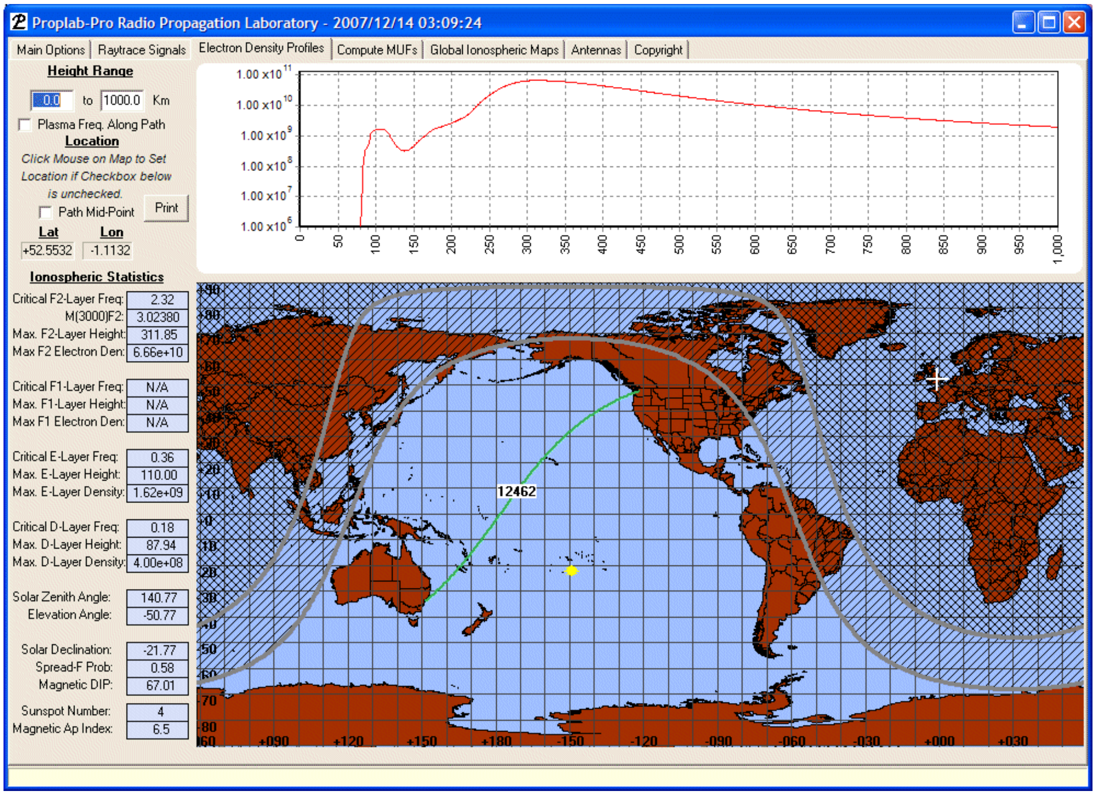
On the other hand, if you are hunting for exotic signal paths – for example, paths that might induce signal ducting to truly great distances (with little attenuation), you can study these charts to help locate regions that will reflect signals sufficiently to cause them to start ducting. You can then use the 3D ray-tracing feature to determine if ducting does indeed occur and what signal properties (frequency, elevation and azimuth) are required to pass signals through the ionospheric ducts to great distances.

You can also use the 3D ray-tracing to determine whether the signal path (or the duct you have found) is bi-static, or supportive of two-way communications. Many ducts are not. A few are. Determining which are likely to support two-way communications, and which are not is something only 3D modeling can answer.



This chart shows what happens if you UN-check the "Plasma Freq. Along Path" checkbox. Notice how the top graph has changed. It now represents the vertical electron density profile over the path mid-point (because the "Path Midpoint" checkbox is checked).

You can discern the D and E region ionization around the 65 to 80 km level, followed quickly thereafter by the intense ionization of the F region. This is a fairly typical daytime electron density profile. During the night, the ionization pattern looks substantially different.



This chart was produced at the point where the white "plus" sign is located on the map over the United Kingdom. To produce this map, we UN-checked the "Path Midpoint" box and then used our mouse to click on the UK region. Once we clicked our mouse, the electron density profile for that location was computed and displayed on the chart at the top.

This is useful for those who need to examine multiple electron density profiles throughout the world.

You will also notice in the above charts that the statistics for the given electron density profiles are shown in the column of boxes at the left. These statistics apply to the path midpoint if the "Path Midpoint" box is checked. Otherwise, they apply to the region where you click your mouse.

The astute observer will notice that the screens shown above are not exactly the same as the screens on Proplab. Two new statistical boxes were added at the bottom-left corner of the screen. The heights of the transmitter and receiver are also displayed as statistics. Clicking your mouse on various locations around the world will change the "Receiver Height" statistic (even though the receiver location doesn't really change). You can therefore determine the altitudes at any location on the Earth with this feature. Simply point and click.

Note that the altitudes displayed are in meters. To convert meters to feet, multiply meters by 3.281. To convert meters to miles, multiply meters by 0.00062137.

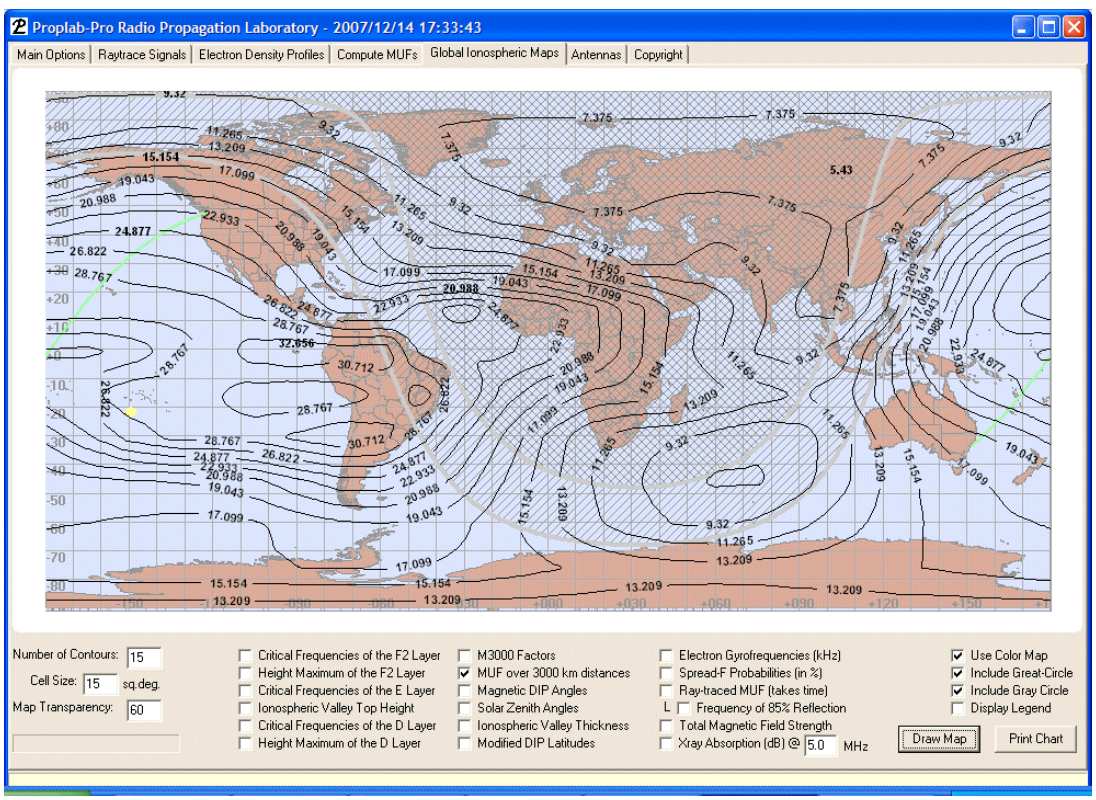
Global Ionospheric Maps

The power of maps.

For navigation, maps are indispensable. The same can be said for the communications specialist who knows how to read ionospheric maps. They can give direction, insight, and improve design goals for communications systems that must meet specific requirements.

Proplab-Pro comes equipped with a complete suite of ionospheric maps. You can chart just about anything from Maximum Useable Frequencies to magnetic field parameters to electron gyrofrequencies to ionospheric valley thicknesses and much more.

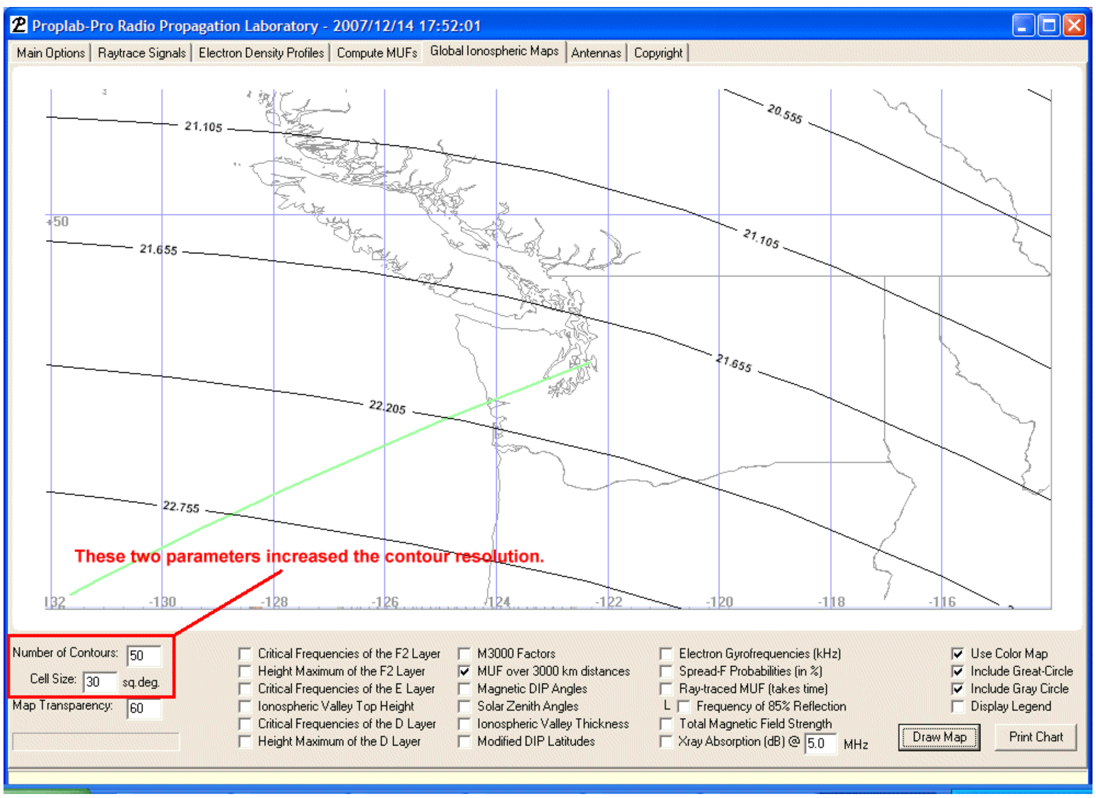
Simply choose your weapon and click on the Draw Map button.



This map shows the maximum useable frequency for 3,000 km path midpoints. In other words, the contour at any specific point is the MUF for any path whose midpoint resides at that contour location.

ZOOMING IN ON DETAILS

One of the coolest and most useful features of Proplab is the ability to zoom in on specific areas of interest.



To produce this map, we used our mouse to point to the **upper-left** corner of the box we wanted to zoom into, left-clicked the mouse and **dragged** the mouse to the **lower-right** corner of the box we wanted to zoom into. When we released the mouse button, Proplab automatically zoomed in on that region and produced a display similar (but less detailed) than this display.

The reason why it was less detailed is because to produce this particular map, we increased the number of contours (see the outlined box) as well as the number of cells (by ***decreasing*** the cell size - the middle box). The “Cell Size” box determines how many cells are used to produce the contours. Since cell size is specified in square degrees, smaller numbers produce more cells, which increases the resolution of the contours.

You can even zoom in multiple times. To **zoom out**, left click on the map and **drag** the mouse toward the **upper-left**, then release the mouse (exactly the opposite of zooming in).

By the way, increasing the number of cells in the contour images to values that are too high can result in an “insufficient resource space” error, which may require you to close down Proplab and reload to resolve (more memory might resolve that issue).

OTHER GLOBAL MAP FEATURES

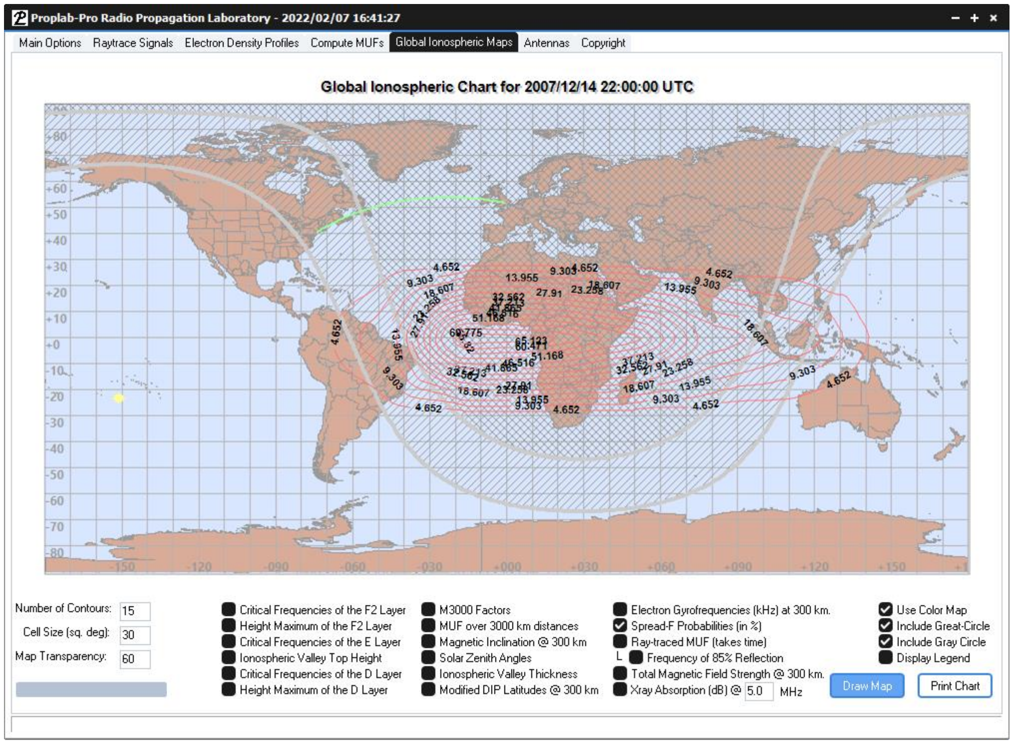
As you can see, a large number of contoured plots can be produced using Proplab, and you have full control over how things appear.

You can draw a full-color map, or a black and white map (better suited for printing charts on a black and white printer) using the appropriate check box at the far lower-right side of the screen.

You can choose to display the great-circle path, or not.

You can choose to display the day/night terminator and gray-lines, or not.

You can choose to display an associated legend on the right side of the chart. This is particularly useful if you are displaying more than one contour at a time. Yes, that is possible. If you want to display more contours, simply check another option and the associated contours will appear, just like magic.

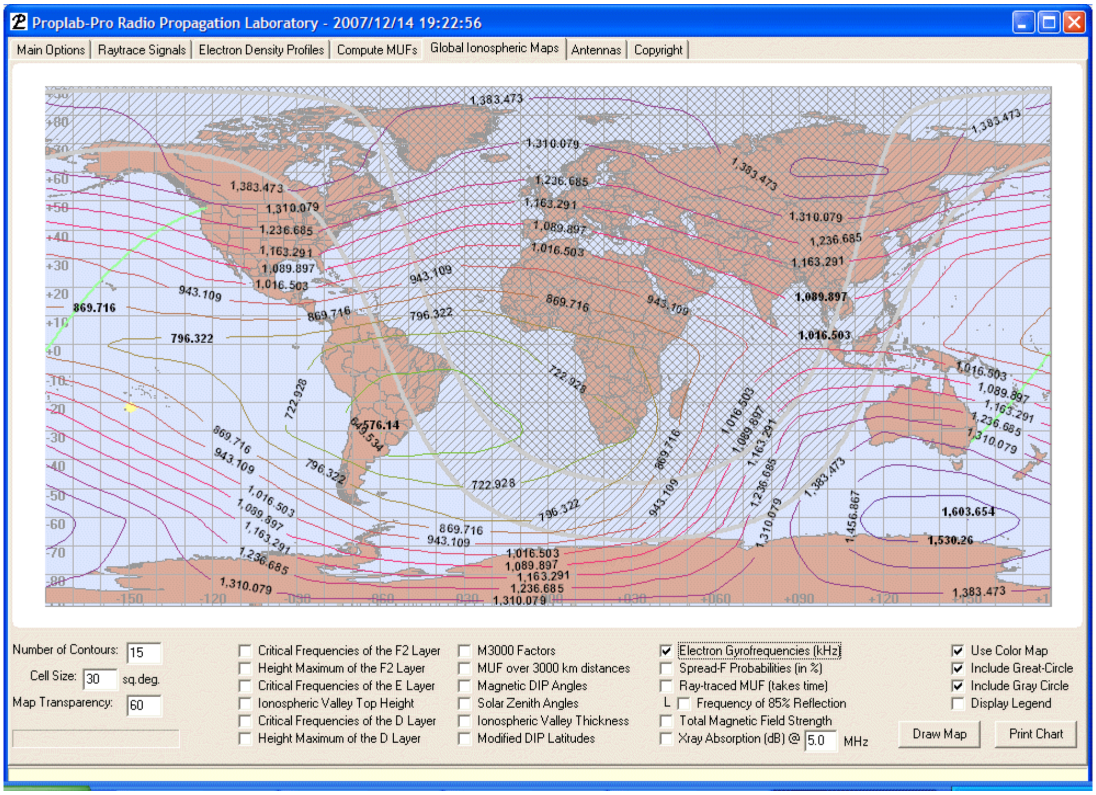


You will notice one other box that has not yet been described: **Map Transparency**. An attractive feature of Proplab is the ability to make the underlying map more or less prominent on the screen. The number typed into the Map Transparency box is a percentage value that determines how dominant the contour lines are compared to the geographical map. Higher values reduce the visibility of the geographical map, which improves the visibility of the contours.

UNDERSTANDING CONTOUR MAPS

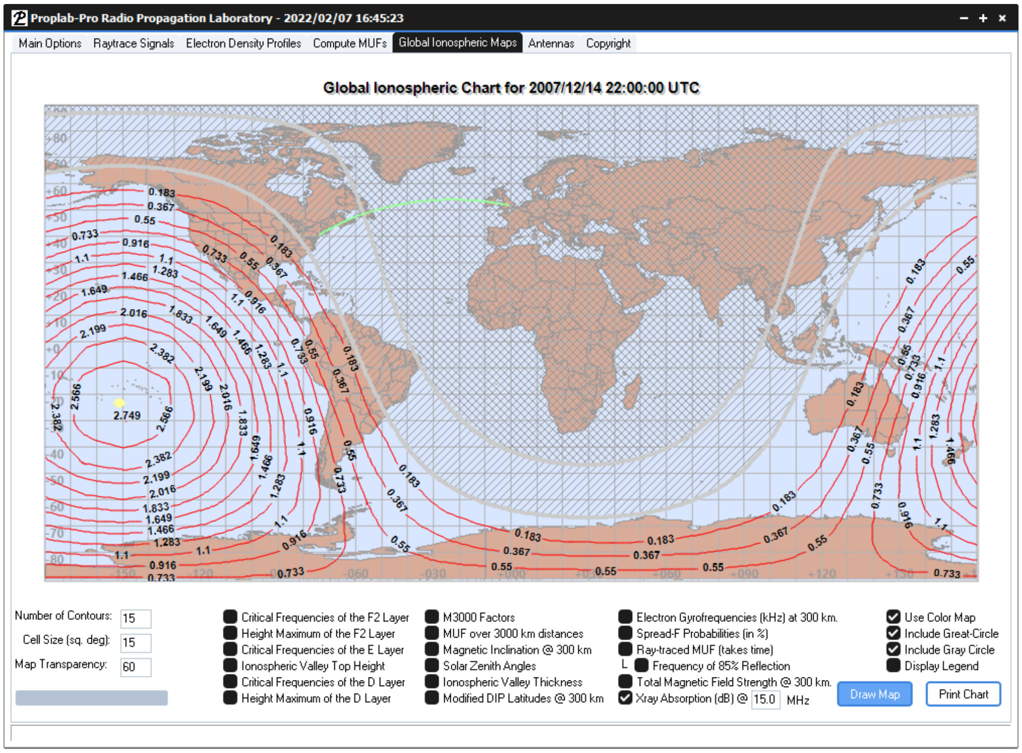
Most of the contour maps that Proplab produces should be self-explanatory. But a few of them are relatively new and so we will give them special attention. If you require an explanation for the other map types, similar maps were produced by Proplab-Pro Version 2, so we would encourage those who need additional assistance to consult the manual for that version of the software.

A new global map produced by Proplab is the electron gyrofrequency map.



Electrons gyrate around the Earth's magnetic field at a frequency that depends on the strength of the Earth's magnetic field. This is important, particularly on low radio frequencies, because the gyration can produce stronger than usual absorption and other effects. The contours represent areas of equal gyrofrequency in Hertz (Hz).

Another new type of chart is the X-ray Absorption chart.



For this chart, we assumed that a powerful class X1.0 solar x-ray flare was in-progress at the time the chart was plotted. The map shows the contours of radio signal absorption (in dB) at a frequency of 15 MHz (see the box to the right of the X-ray Absorption checkbox). You can see that this event would have had a fairly substantial impact on our radio path if our signal would have been transpacific instead of transatlantic.

Max. Useable Frequencies

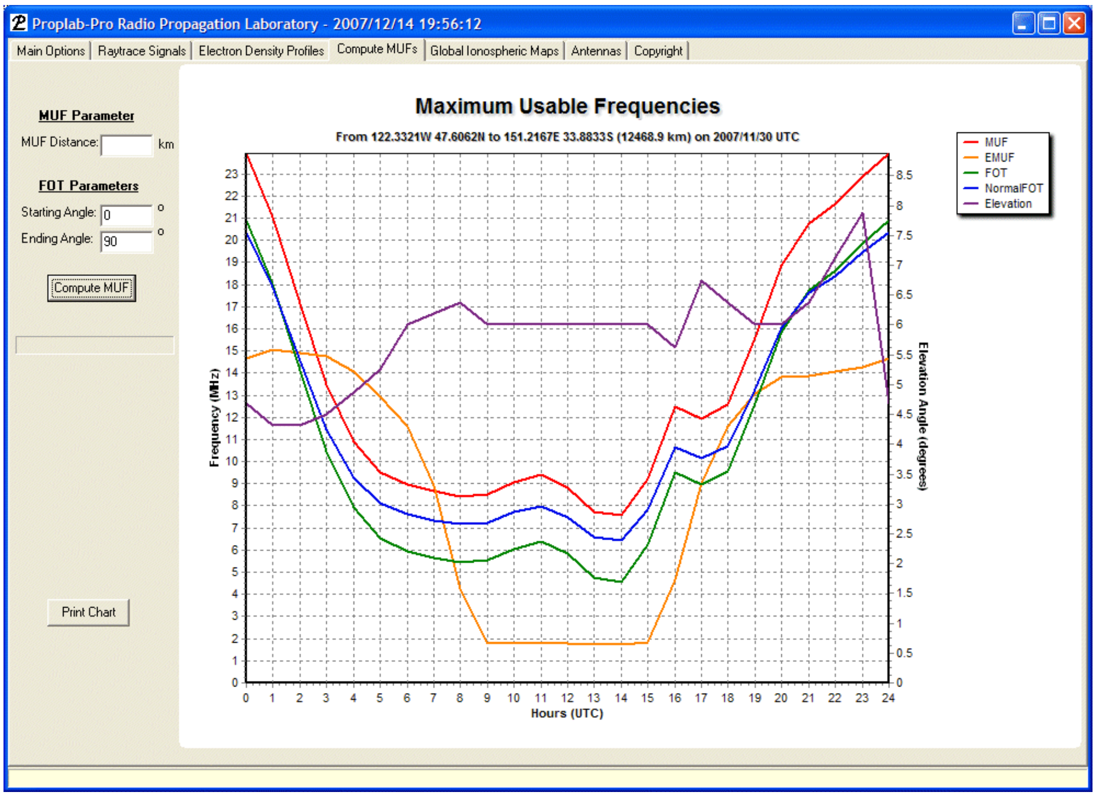
For most radio communicators, knowing the true MUF is a key ingredient for frequency planning.

Proplab-Pro comes equipped with one Maximum Useable Frequency calculator, but it's unlike most other MUF calculators in that it does not use empirical algorithms to compute the MUF. It determines the MUF by physically ray-tracing through the ionosphere repeatedly until the MUF is found. A similar procedure is used to calculate the optimum working frequency (or FOT).

A good discussion of this is available in the older Version 2.0 manual for Proplab-Pro.

Proplab requires more time to compute the MUF and FOT than most other radio communications programs, but then you usually get what you pay for. The greater time taken to physically compute the MUF translates into more reliable results.

To compute the MUF, first establish transmitter and receiver locations. Then click on the “Compute MUFs” tab. Finally, click on the Compute MUF button. A gas gauge will be displayed, showing you the progress of Proplab during the computation phase. When the gas gauge reaches the end, the results are displayed in a chart similar to the following.



The left-side axis refers to the MUF, EMUF, FOT and normal FOT. The right-side axis refers only to the elevation angle. The UTC hour is at the base of the chart.

This plot shows a good deal of information. The ray-trace-determined MUF is shown in red, followed by the maximum useable frequency for the E-region in orange. The ray-trace-determined optimum working frequency (also known as the FOT – why? it’s French) is also computed and displayed together with the normal FOT and the elevation angle required for a signal at the MUF to reach the destination.

Normally, the FOT is computed as simply 85% of the MUF. That is what the "Normal FOT" plot line shows. This differs substantially from the ray-traced FOT. The ray-traced FOT is defined as the highest frequency which will permit 85% of the signal to be refracted back to the Earth. For example, at 12:00 UTC, the FOT is computed to be 5.8 MHz. If the transmitter broadcasts at 5.8 MHz at 12:00 UTC using elevation angles that range from zero to 90 degrees (see the FOT boxes at the left of the plot), the FOT plot shows that 85% of that 5.8 MHz signal would be returned to the Earth between the transmitter and the receiver. 15% of that signal would be lost to space (most likely at the upper-end of the elevation angle range).

Why is this information useful? Because unlike the traditional FOT, this ray-traced definition of the FOT guarantees that 85% of your radiated power will reach the Earth on the given FOT frequency. The same is not true for the FOT computed in the traditional way, as the plot clearly illustrates.

Antenna Selection

Proplab comes pre-built with several standard antenna radiation patterns that can be used to assist in producing more realistic signal analyses.

The selection of an antenna has some serious side-effects and implications that should be considered when performing ray-tracings.

When the transmitter antenna is set to anything other than isotropic (which radiates in all directions equally), the power that is broadcast within the traced rays will conform to the radiation pattern that is determined by the transmitting antennas gain patterns (in both azimuth and elevation).

If you want to examine a broadcast coverage map, you would typically set the transmitting antenna to match the radiation pattern of the transmitters antenna, and then set the receiver antenna to isotropic.

If you don't set the receiver antenna to isotropic, then the results of the ray-tracings will assume that at EVERY POINT that a ray touches the ground, a receiver at that point exists that has the same antenna type that you have defined. Additionally, at every point where a ray touches the ground, the hypothetical antenna at that receiving point will be oriented in the same direction that you specify in the Antenna section of the software setup.

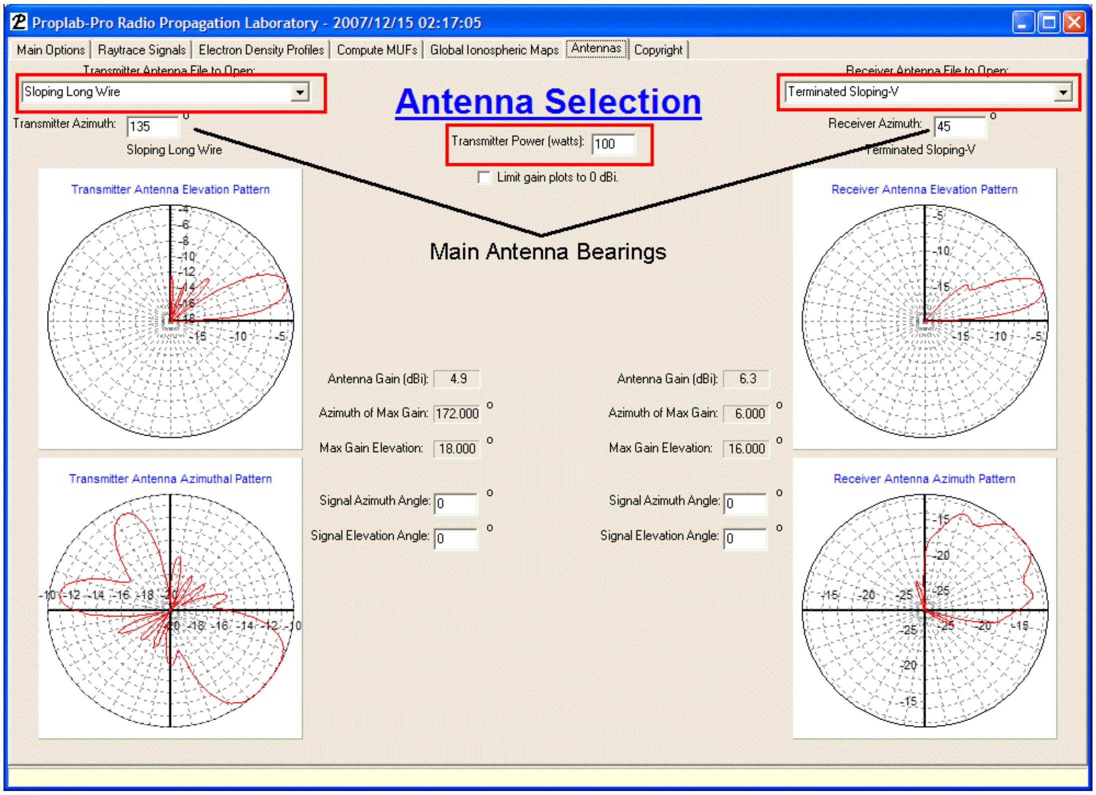
In other words, when you define a receiving antenna in the software, every point where a traced ray touches the ground is processed as though that point was received through your receiving antenna.

This can lead to unexpected results if you don't understand this concept. Since the azimuth of the transmitted signal is constantly changing as it progresses along the great-circle path toward the intended destination (the "receiver location"), if you specify a receiver antenna and then perform a broadcast coverage map analysis, there will be areas of anomalously high or low field strength along the great circle path as the antennas receiving the signal at each ground bounce location receive the signal better or worse, depending on the received azimuth at that point. The only point on the broadcast coverage map that will truly represent the received field strength will be in the vicinity immediately around the actual defined receiver location.

We therefore recommend that for broadcast coverage maps, the receiver antenna be set to isotropic. You can then use the signal strength at the receiver (in the broadcast coverage maps) and manually add in the gain of the antenna to estimate the received signal field strength values at the intended receiver.

If you are only interested in the area relatively close to the receiver and are willing to ignore areas far away from the receiver, then a broadcast map that includes ray-tracings using a receiver antenna can be computed. Just remember that the field strength values a distance away from the receiver where the azimuth of the signal changes will result in less accuracy in the mapped results.

The antenna selection screen is shown below.



The three most important boxes are highlighted. The left-hand drop-down box lets you select a transmitter antenna radiation pattern from the antenna files located in the ANTENNAS folder. The right-side box lets you choose the radiation pattern for the receiver. The center box is where you specify the radiated power of the transmitter, in watts.

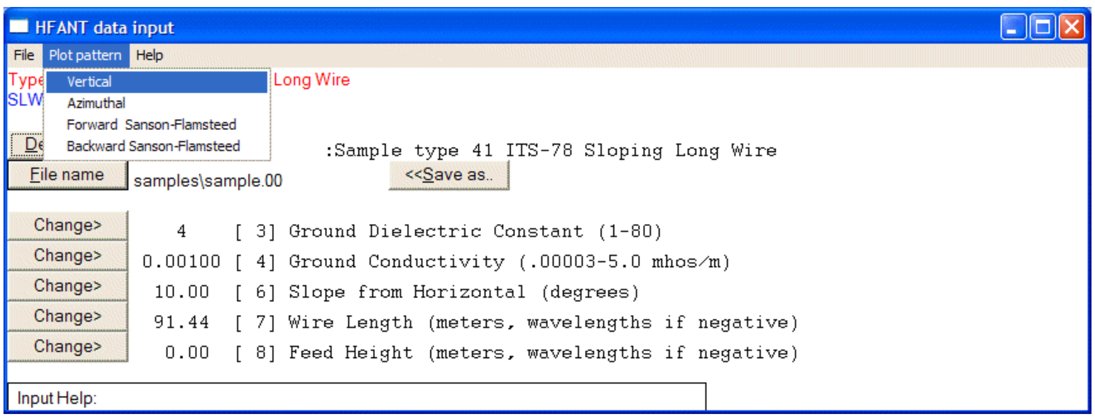
Next in priority are the main antenna bearings, which are also indicated. These are the azimuths (zero degrees being due north) of the main transmission/reception lobes of the antennas selected. As you change the bearings, the radiation pattern angles will be rotated accordingly. Ray-tracing uses these bearings to compute gain factors for the transmitted and received signals.

CREATING YOUR OWN PATTERNS

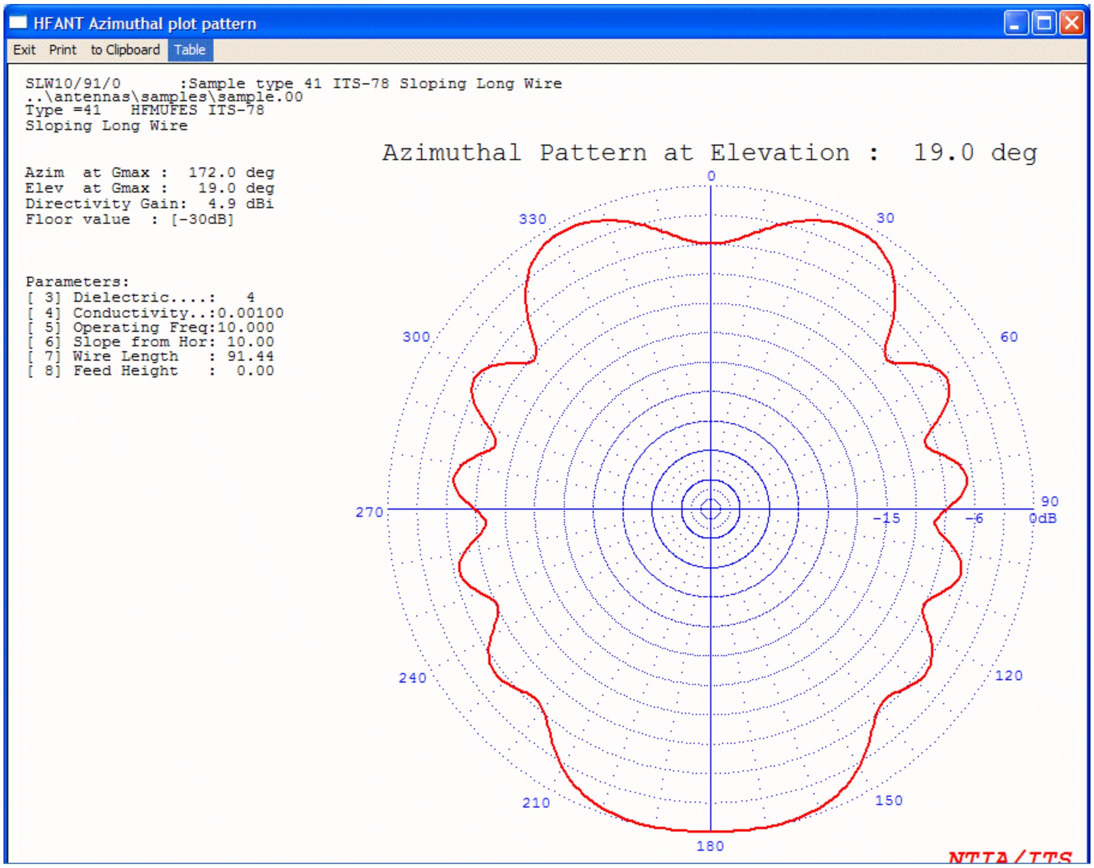
Proplab does not, by itself, have the ability to generate antenna radiation patterns. However, there are other software packages out there (some of them free) that will generate radiation patterns for you. Perhaps one of the simplest and yet easily used is the HFANT program that comes with the free VOACap software package (available on the Internet). Using HFANT, custom antennas can be created and radiation patterns generated.

To help facilitate the use of radiation patterns other than what Proplab comes equipped with, we have created a small utility that, when properly used, will convert radiation files created by VOACap's HFANT program into a file useable by Proplab.

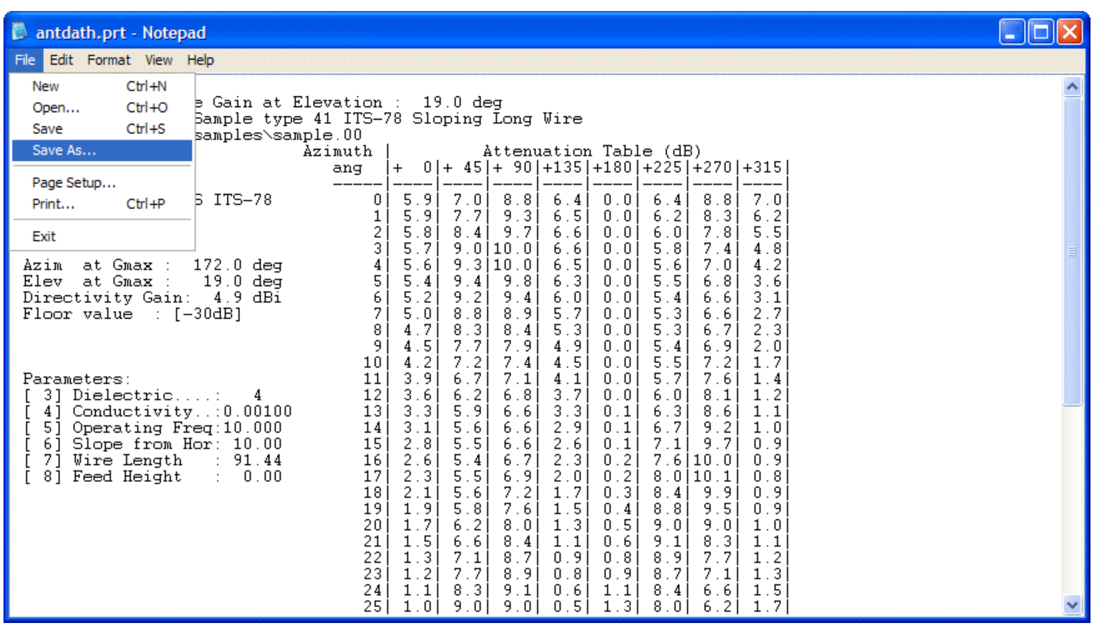
Here is how to do it. First, run HFANT. A screen similar to the following should appear. After it appears, click on the "File name" button and select one of the folders containing antennas. We used the SAMPLE folder and selected the file, SAMPLE.00 (a Sloping Long Wire antenna).



After you have selected an antenna, click on the "Plot pattern" menu option and select the "Azimuthal" choice. An azimuthal radiation pattern for that antenna will be displayed on your screen.



Next, click on the “Table” option and a file will be loaded in a word-processor like Notepad.

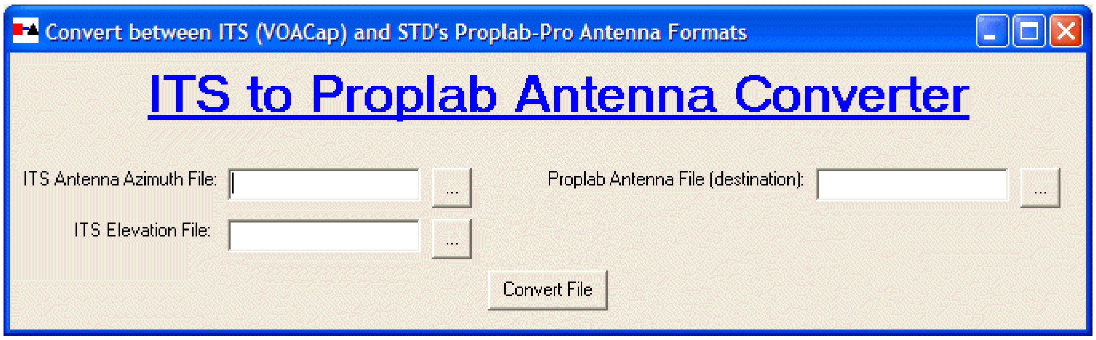


Azimuth	Attenuation Table (dB)							
ang	+ 0	+ 45	+ 90	+135	+180	+225	+270	+315
0	5.9	7.0	8.8	6.4	0.0	6.4	8.8	7.0
1	5.9	7.7	9.3	6.5	0.0	6.2	8.3	6.2
2	5.8	8.4	9.7	6.6	0.0	6.0	7.8	5.5
3	5.7	9.0	10.0	6.6	0.0	5.8	7.4	4.8
4	5.6	9.3	10.0	6.5	0.0	5.6	7.0	4.2
5	5.4	9.4	9.8	6.3	0.0	5.5	6.8	3.6
6	5.2	9.2	9.4	6.0	0.0	5.4	6.6	3.1
7	5.0	8.8	8.9	5.7	0.0	5.3	6.6	2.7
8	4.7	8.3	8.4	5.3	0.0	5.3	6.7	2.3
9	4.5	7.7	7.9	4.9	0.0	5.4	6.9	2.0
10	4.2	7.2	7.4	4.5	0.0	5.5	7.2	1.7
11	3.9	6.7	7.1	4.1	0.0	5.7	7.6	1.4
12	3.6	6.2	6.8	3.7	0.0	6.0	8.1	1.2
13	3.3	5.9	6.6	3.3	0.1	6.3	8.6	1.1
14	3.1	5.6	6.6	2.9	0.1	6.7	9.2	1.0
15	2.8	5.5	6.6	2.6	0.1	7.1	9.7	0.9
16	2.6	5.4	6.7	2.3	0.2	7.6	10.0	0.9
17	2.3	5.5	6.9	2.0	0.2	8.0	10.1	0.8
18	2.1	5.6	7.2	1.7	0.3	8.4	9.9	0.9
19	1.9	5.8	7.6	1.5	0.4	8.8	9.5	0.9
20	1.7	6.2	8.0	1.3	0.5	9.0	9.0	1.0
21	1.5	6.6	8.4	1.1	0.6	9.1	8.3	1.1
22	1.3	7.1	8.7	0.9	0.8	8.9	7.7	1.2
23	1.2	7.7	8.9	0.8	0.9	8.7	7.1	1.3
24	1.1	8.3	9.1	0.6	1.1	8.4	6.6	1.5
25	1.0	9.0	9.0	0.5	1.3	8.0	6.2	1.7

From the word processor, click on the “File” menu option followed by “Save As…” and save the file as something like “azimuthal.txt” or “slopewire-az.txt”. Try to make sure you specify the “.txt” extension on the filename. Make sure you also save it as a standard text file, not an ANSI or Richtext file, or our conversion utility may not work properly. Remember where you save the text file. You’ll need that file in the next steps.

REPEAT this procedure for the same antenna, but using the “Vertical” menu option and save the resulting file as another text file (something like “vertical.txt” or “slopewire-v.txt”).

Now run the conversion utility, “ITSProplab.”



Click on the “…” button beside the “ITS Antenna Azimuthal File” box and navigate to the folder where you saved the azimuthal text file.

Click on the “…” button beside the “ITS Elevation File” box and select the vertical radiation pattern text file that you saved in the above steps.

Next, click on the “…” button beside the “Proplab Antenna File (destination)” box and navigate to the ANTENNAS folder where Proplab was installed. Under normal circumstances, this will be something like: “C:\Program Files\Solar Terrestrial Dispatch\Proplab3\Antennas”. Type in a file. Don’t include a file extension, or if you do, make certain it is “.dat” or Proplab will not see the file.

Now click the “Convert File” button and, Voila, you’re done! You’ve successfully imported an antenna radiation file from HFANT to Proplab. You can now run Proplab and click on the Antennas folder, then select the new antenna from the drop-down list. Note that the filename is not visible. Rather, the antenna description (i.e. “Sloping long wire”) is displayed instead.

Ray Tracing Radio Signals

The power to model reality is through ray-tracing.

Proplab-Pro Version 2 was considered by many around the world as the most powerful radio propagation diagnostic tool in the world. The biggest drawback was that it was notoriously difficult to set up the software in order to perform the highly prized three-dimensional ray-tracings. And once all of the parameters were properly set up, Version 2 often produced mathematical warnings that “traced rays may be in error.” In almost every case, these errors were the result of signals propagating into regions that had not been anticipated or properly pre-modeled. Version 2 had to guess where a signal would travel and then produce ionospheric electron density profiles for those regions. If the rays traveled into an area that did not have an appropriate profile, errors would often occur.

Back when Version 2 was first created, computers had only a fraction of the computing and memory power that they do today. These fancy tricks of pre-processing ionospheric profiles was used to speed up ray-tracing on the slow machines and minimize memory usage during what is normally a very intensive computational exercise.

More than a decade later, computers have come an immense distance in terms of their computing power and memory. The new technology in computers has provided the base structure upon which to build truly useful ray-tracing technology.

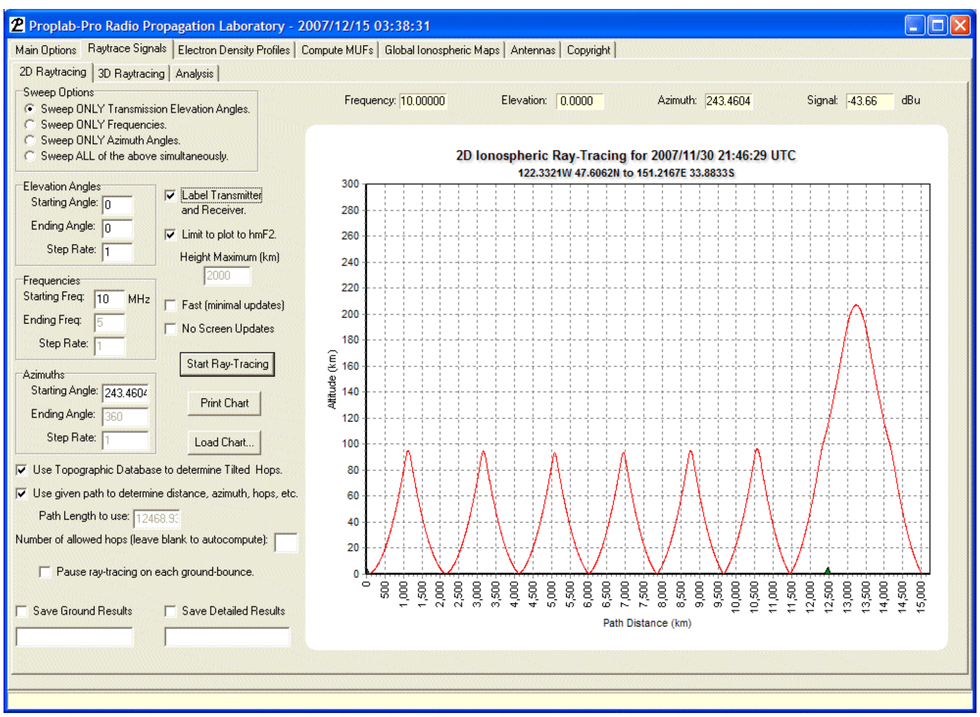
The three-dimensional ray-tracing engine used in Proplab-Pro Version 3 is very similar to the one used in Version 2, but now makes computations of ionospheric electron densities and three-dimensional layer gradients directly, rather than through the use of pre-built profiles. In addition, the new 2007 International Reference Ionosphere is substantially more complex than the old 1995 version of the IRI that was used in Version 2. The end result is significantly easier operation, a definite boost in traced ray accuracy, but results that are produced in a similar period of time. In other words, we considered accuracy and ease of operation to be more important in Version 3 than speed. Computers will always continue to increase in speed (at least, into the foreseeable near-future). As they do, this software will become increasingly functional for real-time 3D operations. For now, on all but perhaps the fastest microprocessors, the 3D component is still most useful as a diagnostic tool.

For those who require faster results or near-real-time results, we have included a fast two-dimensional ray-tracing engine that should suffice for most applications. It sacrifices accuracy for speed.

TWO-DIMENSIONAL RAY-TRACING

For those who require greater speed, we recommend the use of the two dimensional ray-tracing model. In actuality, the 2D model should probably be called a 2.5D model because of its unique ability to compute accurate ground-reflections using a large global topographical database (with a resolution of less than one square kilometer) to determine ground tilts. So although the 2D model is incapable of handling ionospheric layer tilts, it does handle tilted ground reflections (i.e. reflections off mountain ranges) that can cause non-great-circle propagation and signal spreading or multipathing. This is the first time that Proplab has included the ability to model ground tilts and is considered a major enhancement for the software.

The two dimensional ray-tracing engine is extremely simple to use.

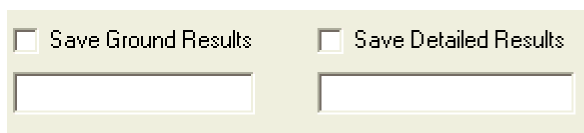


Here is a sample ray-tracing on 10 MHz between Seattle and Sydney on the date specified on the chart and using a take-off (elevation) angle of zero degrees along an azimuth of 243.46 degrees. The receiver is identified by the small triangle 12,500 km down-range. The transmitter and receiver are depicted as triangles when the "Label Transmitter and Receiver" checkbox is checked.

A great deal of flexibility is possible from this screen. You can ray-trace in any direction (or only along the great-circle path), using any range of elevation angles from 0 to 89 degrees, along azimuth's between 0 and 360 degrees or using any frequency from about 1 MHz to any upper limit (although ionospheric reflection is limited to values of about 30 to 50 MHz). You can even zoom in on the results by dragging a box (from the upper-left to the lower-right) around the area of interest. And you can scroll around the zoomed in region by right-dragging your mouse.

Most of the checkboxes and buttons should be self-explanatory. But a few do require explanation.

Ray-tracing is of little benefit unless there is a way to store and review the data that is generated through this process. That is what the two checkboxes are for at the bottom of the chart.



The box on the left stores only the ground-results of each traced ray, such as the ray location, signal field strength, etc. You may use the data generated from this feature more than any other, as it is used to produce broadcast coverage maps, ray-location and hop count maps.

The box on the right stores a copy of each traced ray as it is displayed on the chart. If you need to remember or store precisely how a signal looks when it is traced, click on the right checkbox.

With either checkbox, checking it will bring up another window asking you to type in the name of the file to save.

When you Save Ground Results, it is important to note that a complete copy of all of your software settings are stored in a header file having the same name (but a different extension) as the file you choose for your ray-traced results. This does not happen when you click on the Save Detailed Results checkbox.

Thus, a way is provided for you to store and retrieve multiple ray-tracing scenario's very easily. Normally, when you exit Proplab, a copy of the software settings are stored so that when you next run Proplab, those same settings will be restored. But saving Ground Results produces a separate set of stored settings so that when you retrieve the results for further analysis, the same settings are restored.

GROUND-TILTED RAY REFLECTIONS

As was noted earlier, the two-dimensional ray-tracing engine of Proplab-Pro Version 3 contains the unique ability to determine the direction of ground-reflections using a global high-resolution (less than one square kilometer) topographical database.

To enable topographically dependent ground reflections, make sure that the checkbox labeled "Use Topographic Database to determine Tilted Hops" is checked. There is a small sacrifice of speed to enable this option, as additional hard-disk lookups and some additional mathematical vector trigonometry must be performed on each ground bounce, but overall, the improved results should offset the decrease of any ray-tracing speed.

When using this feature, you will notice (sometimes quite pronounced) changes in the elevation angles of rays that are reflected from the ground. These are legitimate changes that the reflected rays undergo depending on the tilt of the ground around the area where the ray strikes. For example, you will notice significant deviations of rays that are traced along the Rocky Mountains in western North America. There, the chances of a ray being reflected from a tilted ground structure are significantly higher than elsewhere.

Traced rays that are ground-reflected can change in elevation angle **as well as azimuth**! However, the 2D ray-tracing chart will not (can not) show the change that occurs in azimuth. In order to see these changes, you must save the ray-tracing ground results to a file and then further analyze the results using the "Analysis" tab (discussed later). For example, performing a Ray Location analysis, or a Broadcast Map analysis will reveal signals that were ground reflected away from the great-circle path on other azimuths.

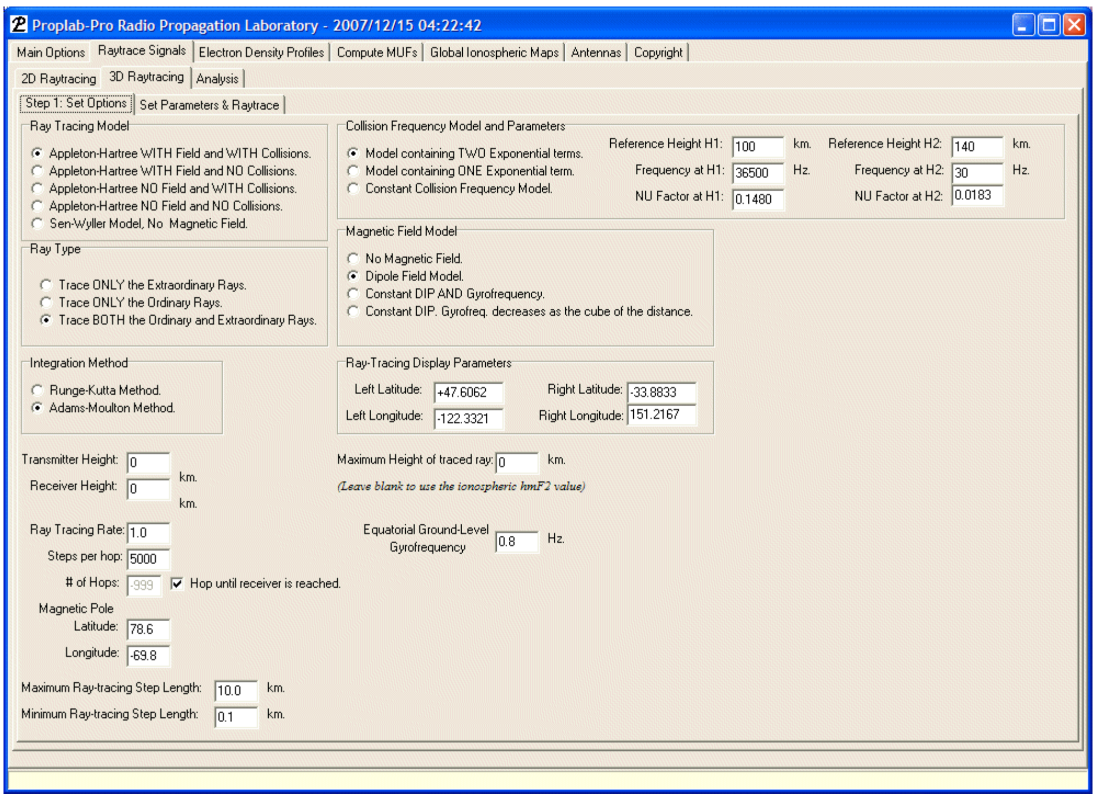
A few screen-captured examples of ground-tilted ray-tracings can be found at the end of the section titled "Ray Location Analysis" (just a few pages from here).

THREE-DIMENSIONAL RAY-TRACING

The three-dimensional ray-tracing engine of Proplab-Pro is the most sophisticated and complex aspect of Proplab. As such, it is also the most time-consuming and computation intensive.

The number of settable options is far larger and more difficult to understand than for the two dimensional case. But the results are unequivocally telling concerning the behavior of radio signals as they propagate through the Earth's ionosphere.

The options are so numerous that a separate options page was required just to display them. Most of the settings the average user of Proplab will never need to touch. The default settings are typically sufficient for most applications.



This is the options page for the three-dimensional ray-tracing engine. For a detailed discussion of these options, we refer you to the manual for Proplab-Pro Version 2.

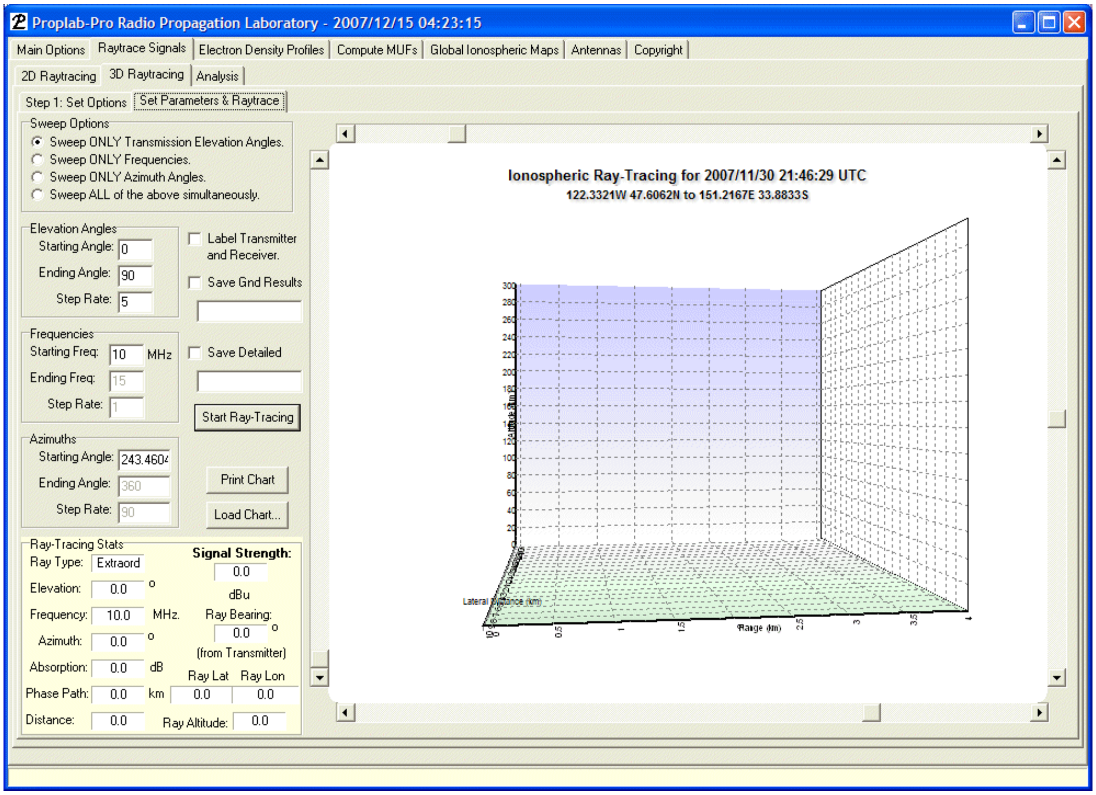
The options that are more likely to be used by the average user are those describing the transmitter and receiver height, the ray-tracing rates and step lengths, the maximum height of the traced ray, and the number of allowed hops.

For most applications, we recommend that the transmitter and receiver heights be left at 0 km. The difference in results between a transmitter or receiver placed at 5 km and those placed at zero km is practically negligible. However, there are instances when perhaps higher altitudes are required. For example, satellites originate at an altitude of several hundred kilometers. Proplab can be used to model such transmissions if negative elevation angles are used. However, azimuths are still measured using the assumption the spacecraft is at ground level. Spacecraft azimuth's should therefore be converted to equivalent ground azimuths before commencing ray-tracing.

The number of allowed hops is self-explanatory. If the checkbox is checked, Proplab will ray-trace until either the "Maximum Height of Traced Ray" value is reached or exceeded (if this value is blank, the hmF2 value is automatically used), or until the traced ray reaches or exceeds the receiver distance.

The ray-tracing step lengths and tracing rates can be adjusted to speed up ray-tracing functions. But doing so will sacrifice accuracy and may even introduce anomalous (completely inaccurate) ray-tracing results if the lengths or rates are set to values that are too large.

After the 3D ray-tracing options have been set up, the next tab "Set Parameters & Raytrace" can be clicked.



This is where you set up the primary parameters of the ray-tracing. It is almost identical to the 2D ray-tracing screen.

Note that negative elevation angles can be specified (unlike for the 2D rays) if the height of the transmitter is some distance above the ground. There are additional complications that can occur if the transmitter is placed in the wrong location / height with respect to the ionosphere. For example, if the transmitter is placed in a region of the ionosphere where the frequency of the transmitter is less than the critical frequency in which the transmitter is immersed, the ray can not be traced. The radiated signal waves become “evanescent” in these regions. Evanescent waves decay exponentially with distance and very quickly vanish (which is precisely what “evanescent” means: to quickly vanish). So some care should be exercised in the placement of a transmitter within the ionosphere to ensure that the frequency of the transmission is higher than the local plasma frequency around the transmitter.

For users of the old Proplab-Pro Version 2, the first striking difference will be the three-dimensional display and the scroll-bars surrounding that display. Using those scroll-bars, you can rotate anywhere around the 3D grid (even while rays are being traced). You an also change the perspective and/or zoom in or out. It’s a very flexible 3D display.

The next striking difference will be the lack of additional required setup. The old Proplab-Pro Version 2 required a ***significant*** amount of additional setup in order to pre-generate ionospheric profiles where the ray-traced signal was predicted to travel. All of that work is now history with Version 3. After you establish the radio path (using the Map Options tab), all you need to do is specify the transmission parameters (elevation angle of the transmission, azimuth, frequency, etc). That's it. Click the "Start Ray-Tracing" button.

Now, Proplab-Pro Version 3 does all of the work of computing electron density gradients and other complex tasks internally and does not require pre-generated profiles to function. The result? No more errors or inaccurately traced rays. Every ray that is traced is able to obtain all of the information needed to accurately complete the ray-tracing. That is a significant advancement for Proplab and should improve user friendliness considerably.

These advancements also explain (in part) why ray-tracings continue to be relatively slow. Most people forget just how complex a problem physics-based ionospheric ray-tracing is. Fortunately, computer technology is now becoming fast enough to make more practical use of it.

The speed of the ray-tracings is also affected by the IRI model settings that are established. The IRI NeQuick model is definitely the fastest model/mode to use for ray-tracings. A fairly large increase in ray-tracing time is also required if you use the new D-Region model where Winter Anomaly or Stratospheric Warming information can be supplied. When that D-region model is enabled, the structure of the lower ionospheric electron densities is altered to fit the observations of many rocket-flight investigations into D-region morphology. Since that model also takes into consideration D-region enhancements due to winter anomaly and stratospheric warming events, it may be a desireable option to enable. However, the increased complexity of the electron densities that result from inclusion of this model will increase the time required for rays to be traced through that region. On the other hand, the additional time and the new D-region model may also increase the accuracy of traced rays and computed signal absorption levels.

The only other two features of this screen that merit some attention are the two checkboxes "Save Gnd Results" and "Save Detailed."

To save the ground results of 3D ray-tracings, click the "Save Gnd Results" checkbox and select a filename to save the data to. After you have done that, perform a 3D ray-tracing and the results of each ray that reaches the ground will be saved to the file specified. After a ray-tracing session has been completed, you can analyze the results by clicking on the Analysis tab (discussed in the next section).

Occasionally, you will perform a 3D ray-tracing that may contain chart features that you would like to remember. You can save the detailed structure of the ray-tracings displayed on the chart by clicking on the "Save Detailed" checkbox. The only difference between this checkbox and the one for saving ground data is that this detailed checkbox should be checked **after** you have performed a ray-tracing.

To load a previously saved detailed chart, click the "Load Chart..." button.

Analysis

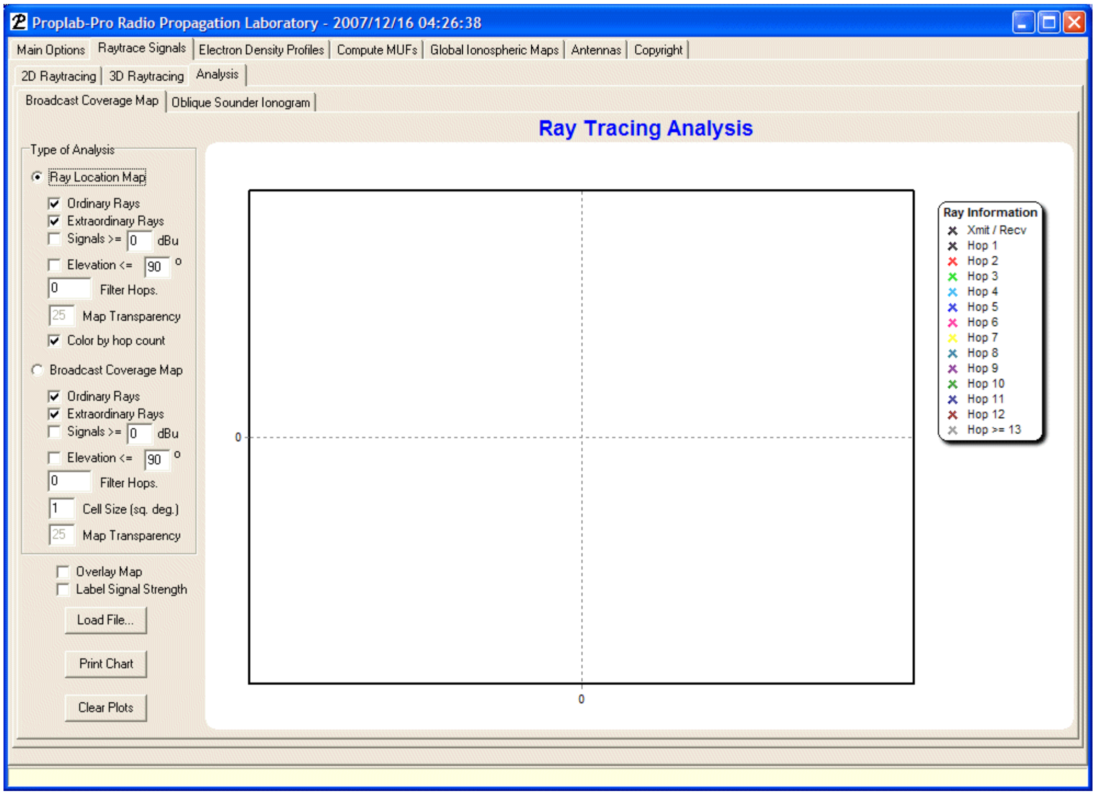
The only way to really know is through analysis.

It may seem like something of hindrance to have to spend time running a ray-tracing analysis before you can see the results. Society today is driven by the demand for instant satisfaction. Even most radio propagation programs nowadays provide instant gratification by displaying plots of radio behavior (even broadcast coverage maps) in real-time. But in the real-world, for those who really need to know, short-cuts are not desireable, because they hide the details. Any good scientific effort involves data collection followed by analysis. The same is true for Proplab. If you want reliable results, spend the time to gather the data, and then pursue the analysis.

Proplab comes with three powerful analysis tools which can be used to diagnose almost any ray-tracing problem.

RAY LOCATION ANALYSIS

All of the analyses produced by Proplab involve a study of the characteristics of the signal rays as they reach the ground. A significant amount of information can be gleaned from a study of the type of signal that reaches the ground. For example, how many hops has the signal taken? What is the signal field strength? What elevation angle was required to get the signal where it hit the ground? Was it the ordinary wave, or the extraordinary wave? There are specific patterns that form on the ground when ray location analyses are performed. These patterns can help you identify such things as signal focusing and defocusing, etc.



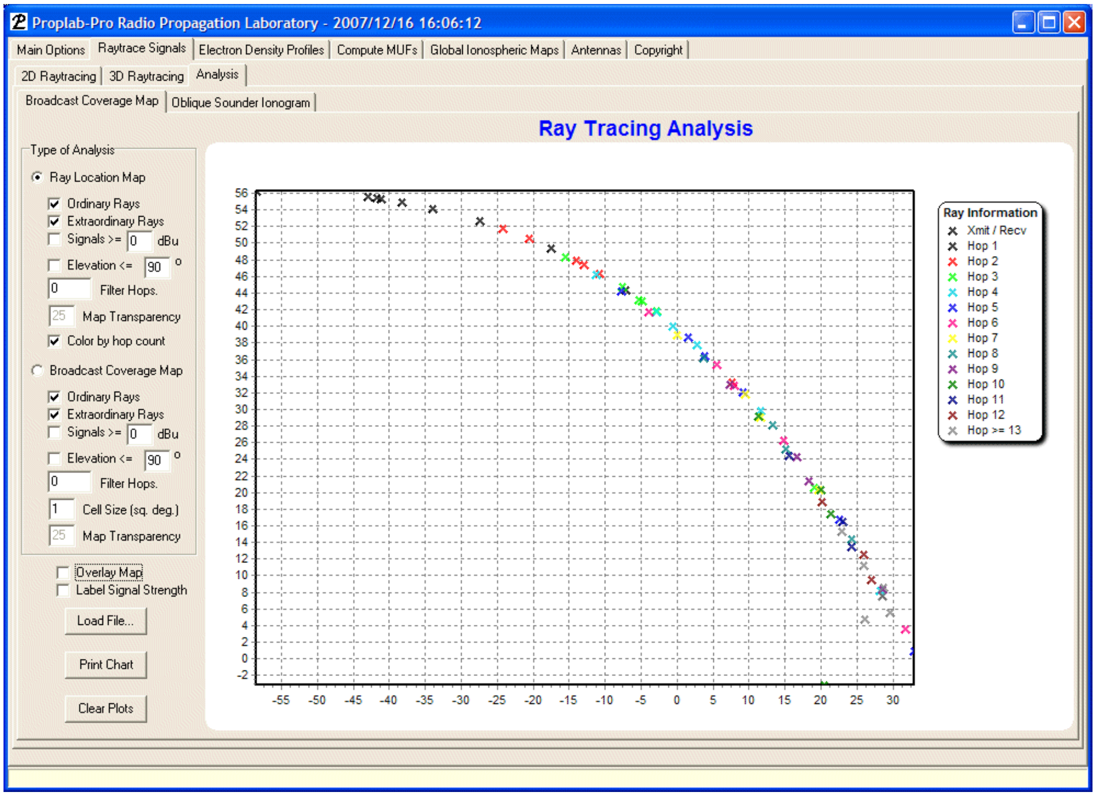
This is the screen you will first see before you load ray-tracing results into the system. There is very little you can do until you click on the “Load File…” button.

Remember that you cannot Load a File until you have first Saved Ground Results from a previous ray-tracing session (either a 2D or a 3D session).

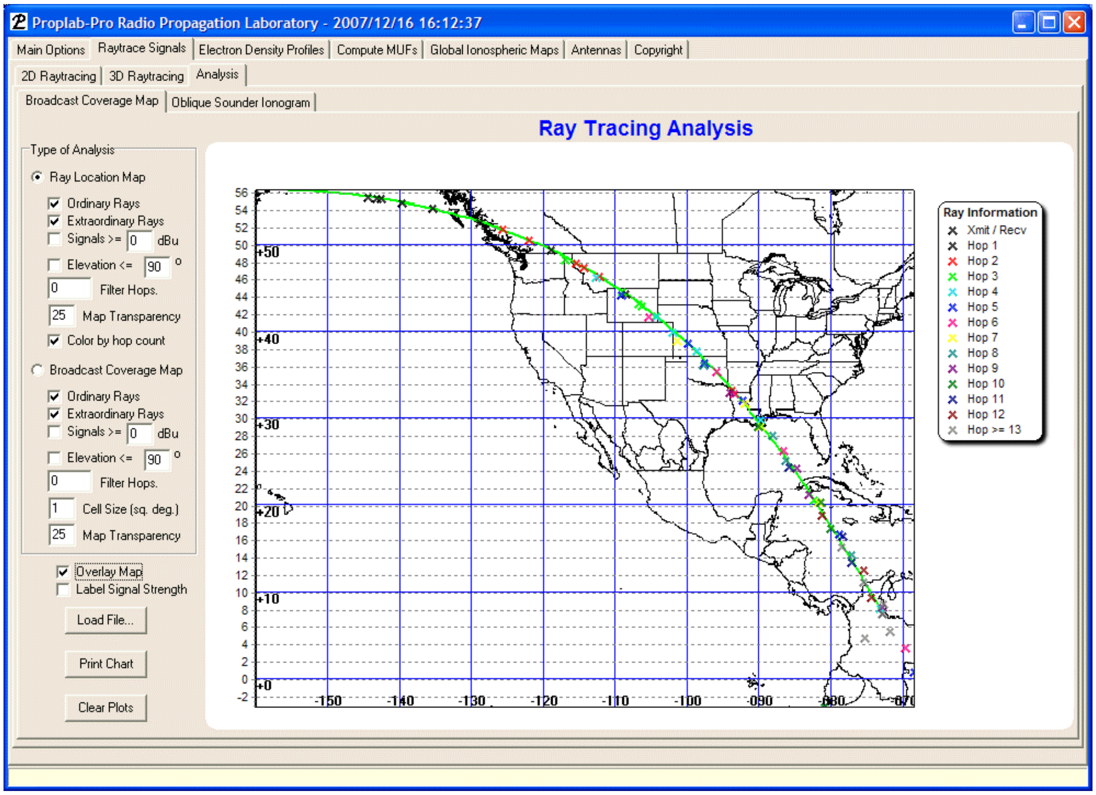
When you load a file, Proplab warns you that proceeding will cause your current Proplab settings to be completely replaced by the settings that were present at the time that the ray-tracing session you are loading was active. In other words, if you have set up a transmitter and receiver pair, and if that pair differs from the pair that were used during the ray-tracing session you want to analyze, then loading the results of that ray-tracing session will cause your current transmitter and receiver pair to be replaced by the transmitter and receiver pair that were used during that ray-tracing session. But the effect is not just limited to the transmitter and receiver pair. It is global in nature. **All** of the settings in Proplab are replaced. This is required in order to ensure that none of the information related to the ray-tracing sessions is lost when analyses commence.

If you need to save your settings before commencing an analysis, you can save them to a file of your choosing by clicking on the Main Options tab followed by the Other Options tab. Then simply click the “Save” button and specify a file.

When you start analyzing the results of prior ray-tracing sessions, please refrain from changing important parameters such as the signal path or transmitter/receiver pairs. Doing so might affect the way Proplab displays the analysis results (display limits, great-circle paths, etc.).



Here is what the ray-location display looks like after performing a very simple single-azimuth ray-tracing. The left axis represents latitude and the bottom axis represents true longitudinal **spacing**. The bottom longitudinal markings should not be associated with true geographical longitudes because a map has not been associated with the data. In this mode (when a map has not been overlaid), the longitude marks are simply there for reference and do not refer to a specific geographical location on the Earth. This is difficult to explain without another supplemental display that uses the same data, but has the associated geographical map overlaid upon it.

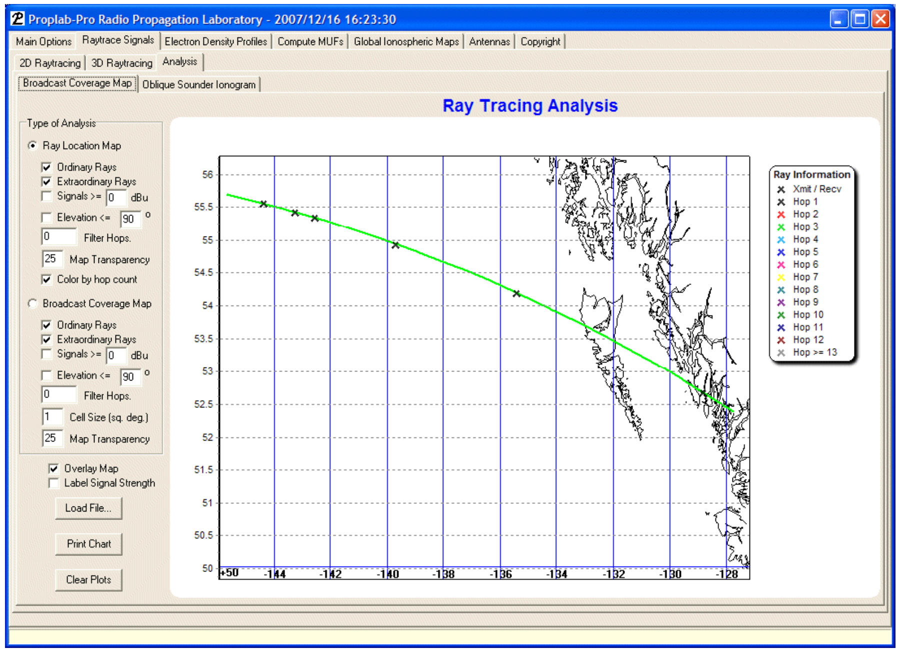


By clicking on the “Overlay Map” checkbox, the correct geographical map and great-circle path is displayed. Notice that true longitudes are also displayed and that these lines of longitude differ from those in the previous map. **However**, the longitudes displayed on the previous map were still valid lines of longitude. But the absolute values of those marks were not associated with the true geographic grid as the above map is.

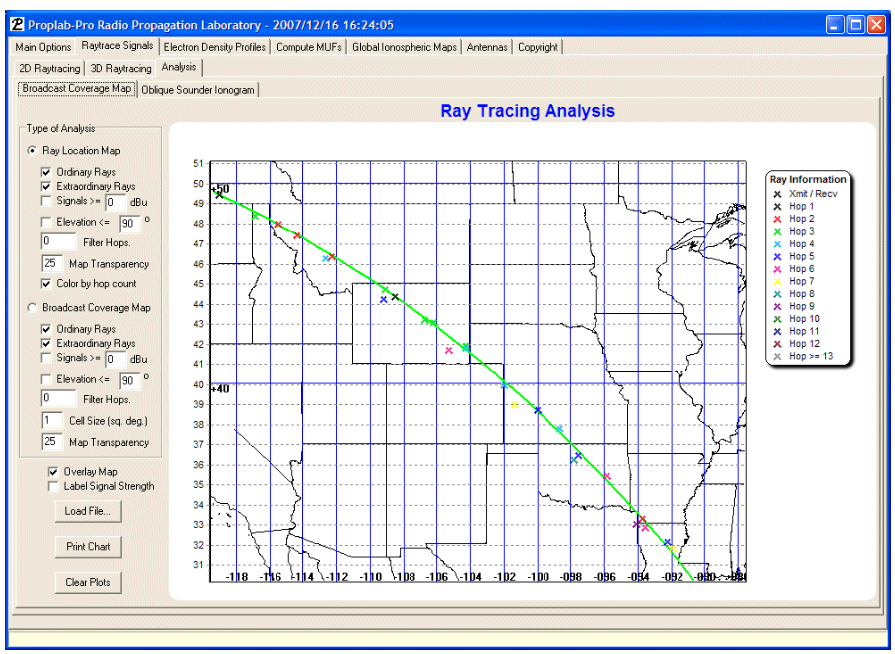
The transmitter in the above example is at the extreme upper-left corner, and the receiver is located in Colombia and uses a frequency of 5 MHz. Notice that the “Color by hop count” checkbox is checked so that each ground bounce is identified by the number of hops it took for the signal to get there.

Also notice that we are not filtering signals out by signal field strength (the “Signals >=” checkbox is not checked), and we are accepting both ordinary and ordinary rays (although in this 2D ray-tracing, only ordinary rays are modeled). We also are not filtering out signals according to the elevation angles of the transmitted rays. So this result shows every signal ray that was generated during the ray-tracing session.

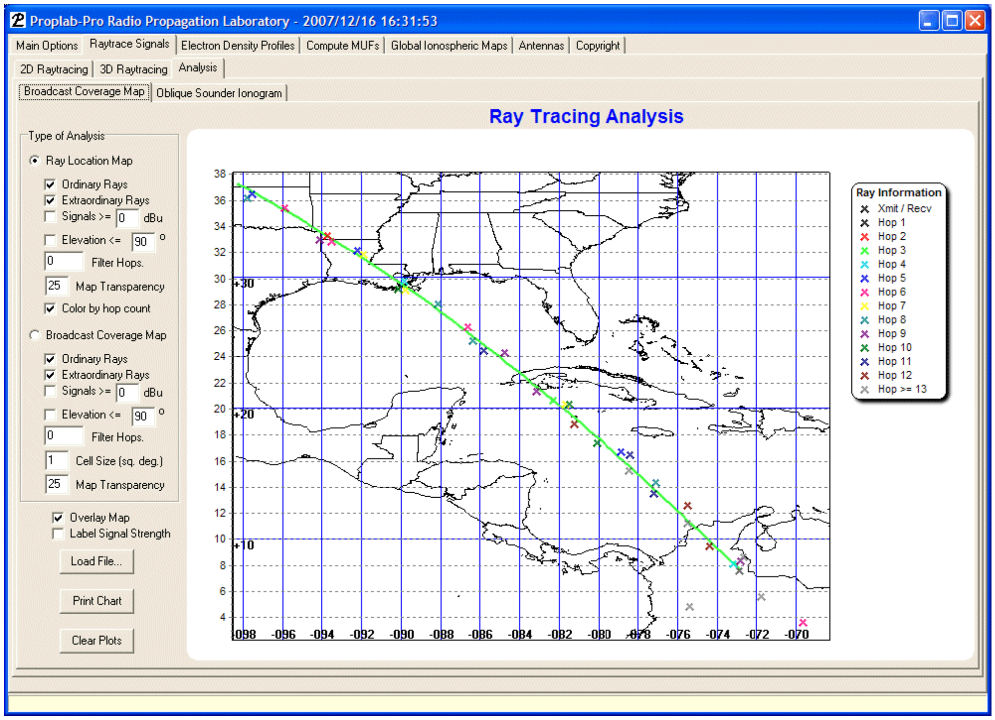
It is also interesting to note that for this example, the “Use Topographic data to determine Tilted Hops” checkbox was checked (turned on) during the 2D ray-tracing session. The results of this are visible in the analysis.



This zoomed in view over the ocean (towards British Columbia Canada) shows that the flat ocean produces normal ground bounces that do not deviate from the great-circle path.



Now we zoom in over the United States where the signal starts to bounce off of tilted ground surfaces and deviate from the great-circle path. But notice that no significant tilts were hit because the deviations are still relatively small.

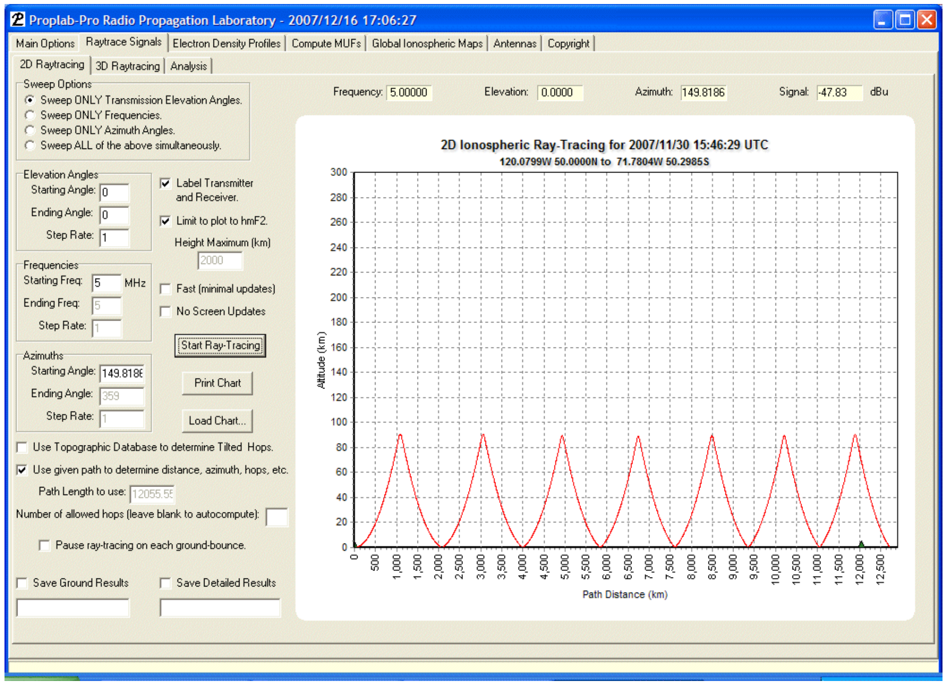


No additional significant deviations occur over the relatively flat land of the southern U.S., but the small deviations that occurred over the northern Rocky Mountains are causing additional signal spreading the further the signal travels.

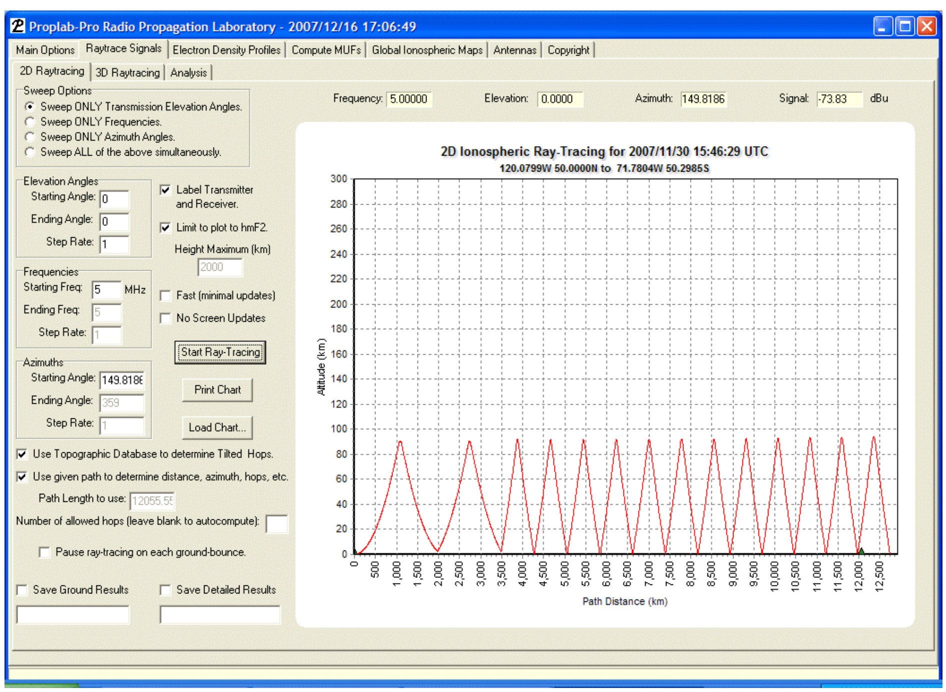
You will notice that somewhere, most likely between Cuba and Columbia, one of the signal components bounces off of something quite tilted because there is one lone signal that reaches the ground considerably off-course near 75W and 5N. Although that signal component took at least 13 hops to reach that location (and thus the signal is probably well below the local noise level), it illustrates the important impact that including ground tilts can have on signal propagation.

If we had extended the distance of our ray-tracings, you would have found that that one lone non-great-circle signal component would have continued propagating on its new azimuth.

Tilted ground hops are also easily discernable while performing ray-tracings.



This is an example of a signal that was ray-traced ***without*** the topographic tilted hop feature. Notice that the signal is reflected nice and evenly from the ground to the lower E-region where it was reflected. Compare this to the results below where tilts are turned **on**.



The first ground bounce is clearly tilted, causing the signal to be reflected at a higher elevation angle. The second ground bounce is also tilted, causing the elevation angle to be increased even further.

It is possible that this signal was reflected out of the great-circle plane. This cannot be determined unless the ground results are saved to a file and then further analyzed using the Ray Location Analysis feature here described.

One of the most pronounced effects of this example is the significant increase in the hop count required for the signal to reach the receiver. With ground tilts turned off, the signal requires six hops. With ground tilts turned on, the signal requires thirteen hops, more than double the number originally anticipated.

Consider what inclusion of these effects would have on the strength of signals. By more than doubling the ground hops and D-layer absorption, the tilted ground hops produced an additional 26 dB of signal loss! That is a significant amount of signal loss that can be attributed solely to the effects of a tilted ground.

Perhaps now we are starting to realize the importance of ***detail*** that only ray-tracing can produce. Empirically-based algorithms blur reality and will not help explain many of the oddities that can occur in ionospheric radio propagation.

BROADCAST COVERAGE MAPS

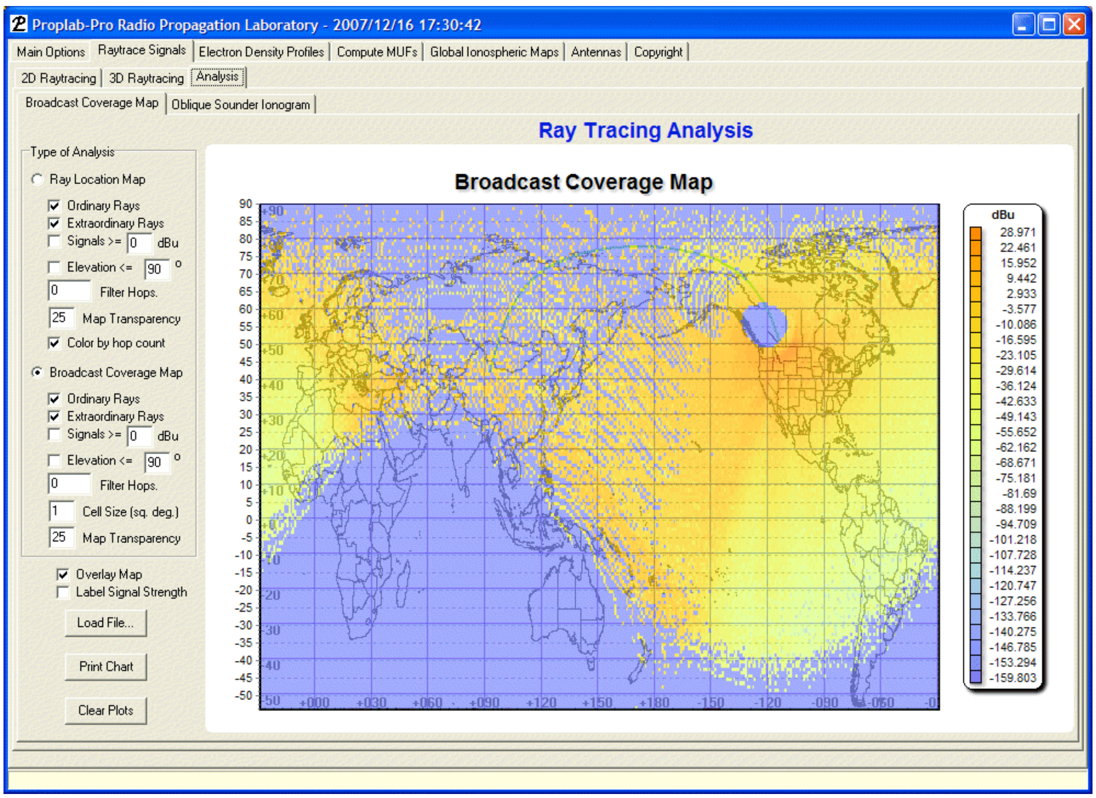
All good radio propagation prediction programs produce broadcast coverage maps, or maps of signal field strength over area. But once again, those based on empirical or simplistic algorithms will blur reality and fail to reveal hidden details that radio designers and communications specialists could use to improve their decisions. Proplab is like the drill that will allow you to drill down and see the details that no other tool can provide.

Fortunately, the increased speed of computers today allow 2D ray-tracings (even with tilted ground hops enabled) to be produced with significant detail over just an hour or two of computing time – or a few additional hours on more conventional computer systems). Microprocessor speed is key to Proplab. The faster it is, the quicker the results will be produced.

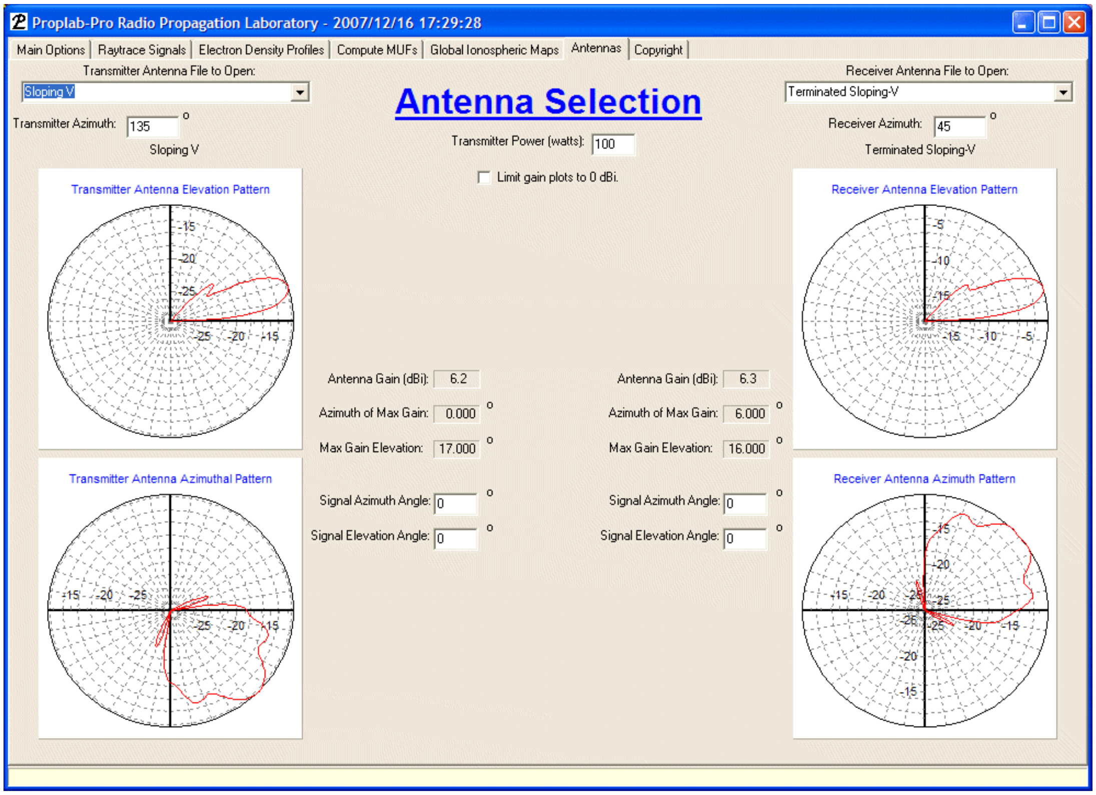
As was stated above, broadcast coverage maps are maps that show signal field strength over an area that you specify when you perform the ray-tracing. If your ray-tracings cover elevation and azimuth, you can display broadcast coverage maps overlaid upon geographical maps. To produce accurate maps, **do not vary frequency** during the ray-tracing sessions, unless you are performing an analysis of spread-spectrum transmissions. If you do vary frequency, those signals of differing frequencies **will** be included in the broadcast coverage map signal field strengths. Proplab does not (as of the current version) distinguish between signals of differing frequencies. As a result, most broadcast coverage and ray-location map analyses use single-frequency transmissions (only elevation angles and azimuths are varied). Varying frequency will also introduce a significant increase in time required to complete a ray-tracing scenario.

To load a ray-tracing session for broadcast coverage map analysis, click on the “Broadcast Coverage Map” checkbox, and then click the “Load File...” button. Specify the file containing your ray-tracing results for analysis.

Here is an example broadcast coverage map that was produced at 5 MHz over a 360 degree azimuthal range and spanning elevation angles from 0 to 89 degrees, all at 1 degree increments.



The signal path is from central Asia to southwestern Canada. The antenna’s used and their characteristics are shown below.

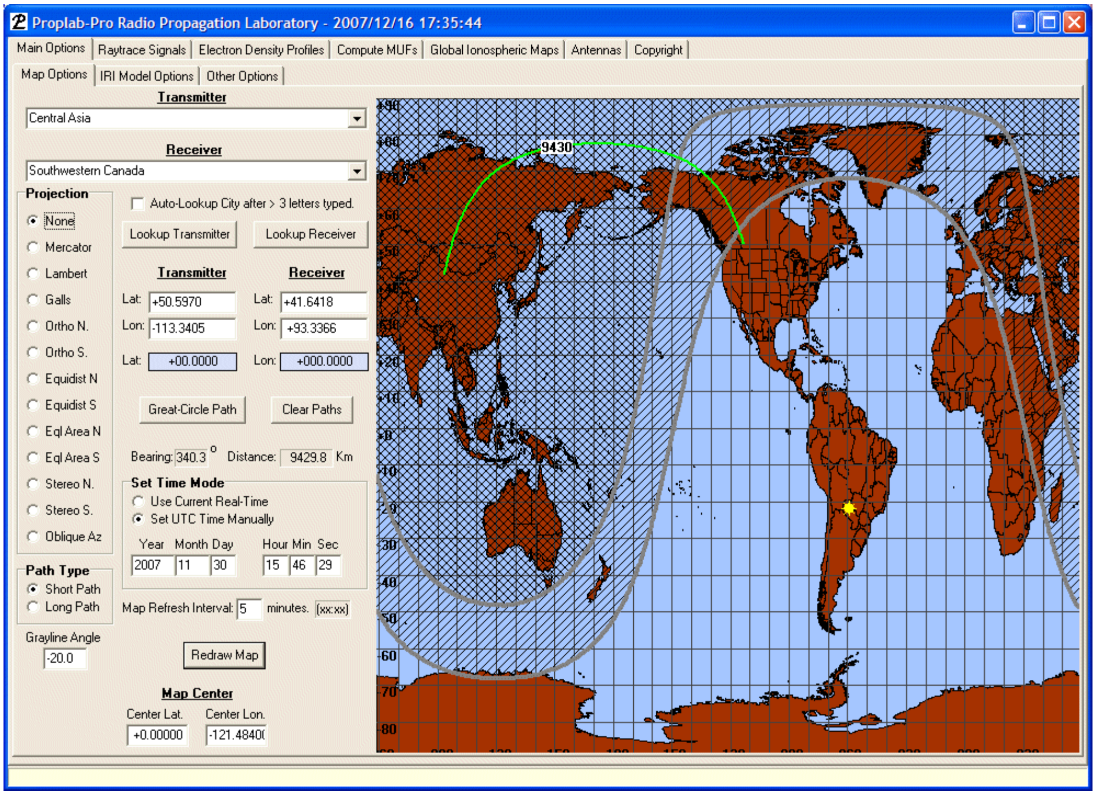


The transmitter power used was 100 watts at an azimuth of 135 degrees (southwest).

The receiving antenna was slightly different (a terminated sloping V as compared to a Sloping V), and was oriented with its main gain lobe at an azimuth of 45 degrees (northeast).

Looking back at the broadcast coverage map and the options that were used, you will notice that the settings permit **all** of the signals (regardless of signal field strength) to be plotted. The bar-graph at the right of the display shows the large variance in field strength.

The map showing the great-circle path is displayed below so that some idea of where the Sun was can also be used to paint the picture of this scenario with greater clarity.

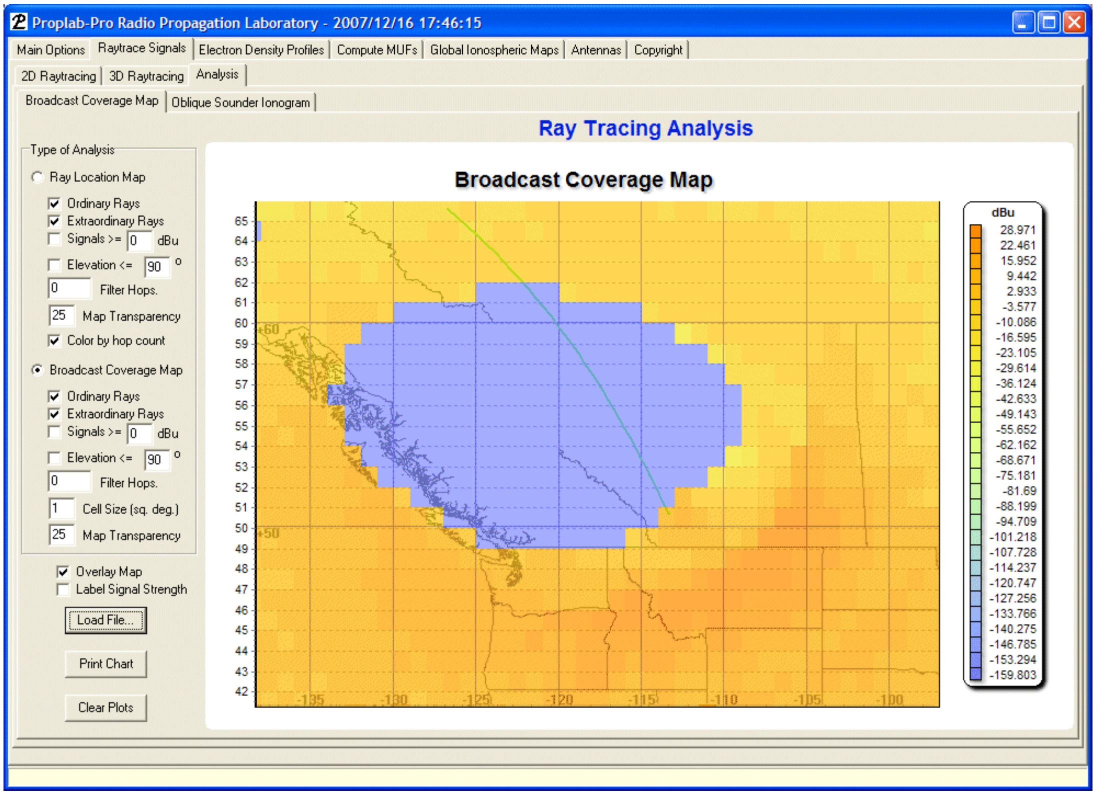


Notice that the sunrise/sunset terminator just passed the transmitter in southwestern Canada. On frequencies of 5 MHz, signal absorption will be greatest toward the southeast. Unfortunately for us, our transmitter's main radiation lobe is oriented almost 180 degrees away from our desired great-circle path and ***toward*** that zone of highest absorption. We might therefore expect poor reception results at the receiver. The only positive for this scenario is that the main lobe of the receiving antenna is pointed more or less in the direction of reception. This scenario is therefore like a problem where an Asian receiver wants to try and pick up a transmitter that is most focused on the continental United States..

The Sun's impact on signal absorption is clearly evident on the broadcast coverage map, for signal field strength drops off rapidly on azimuths that carry this signal into the sunlit ionosphere.

The skip-zone is also clearly visible as the hole of no signal reception. But notice that this hole is not centered on the transmitter. The proximity of the Sun's ionizing influence is readily apparent, for signals transmitted toward the southeast are able to be received much closer to the receiver than signals that are transmitted toward the northwest (toward the region of darkness).

Here is a zoomed-in view of the skip-zone hole.

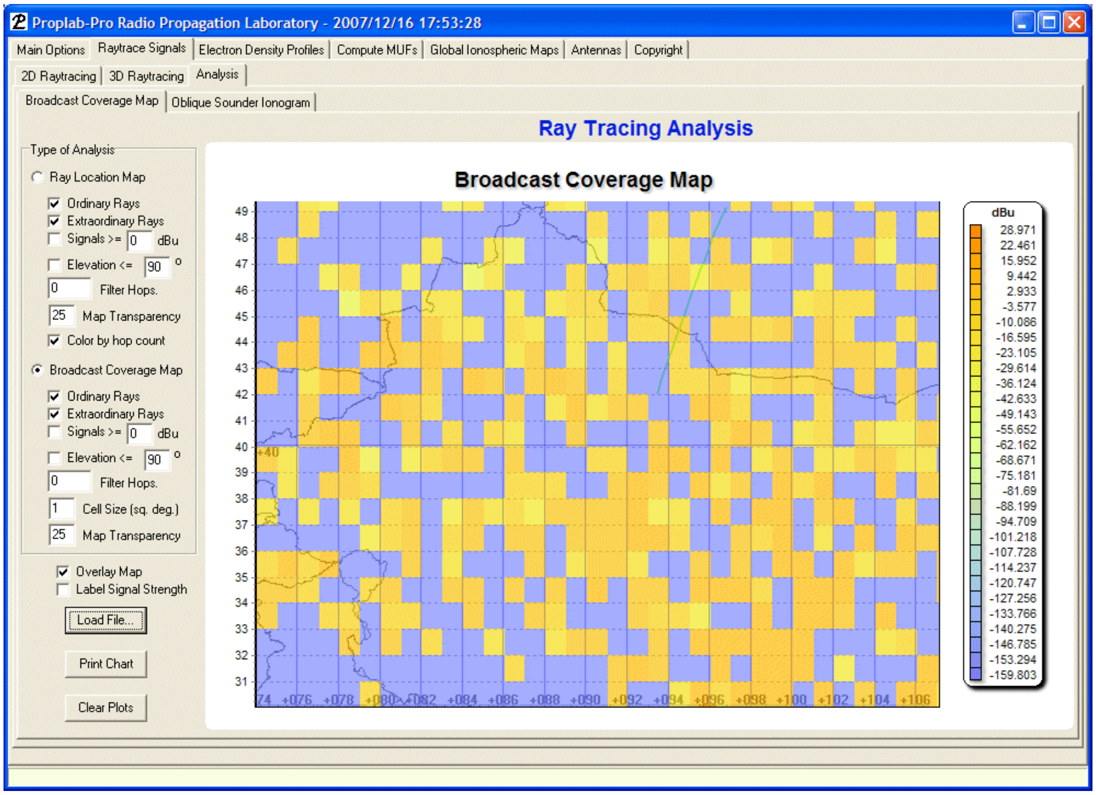


From this image, it is clear that even vertically propagation 5 MHz signals will reach the ground immediately around the transmitter with respectable strength. Thus, 5 MHz propagation is possible everywhere toward the southeast for some distance.

You will also notice that the area of maximum signal field strength is located from approximately central Idaho and central/southern Montana and into south-central Saskatchewan. This is the result of the main transmission lobe of the transmitter being oriented toward the southeast.

The cutoff between no signal and strong signal is very pronounced in this example. The extreme northern region of Washington state, as well as Vancouver Island would be on the cusp of this skip-zone, where signal focusing would produce periods of strong signals and periods of complete signal loss.

So what is the picture like at the receiver?

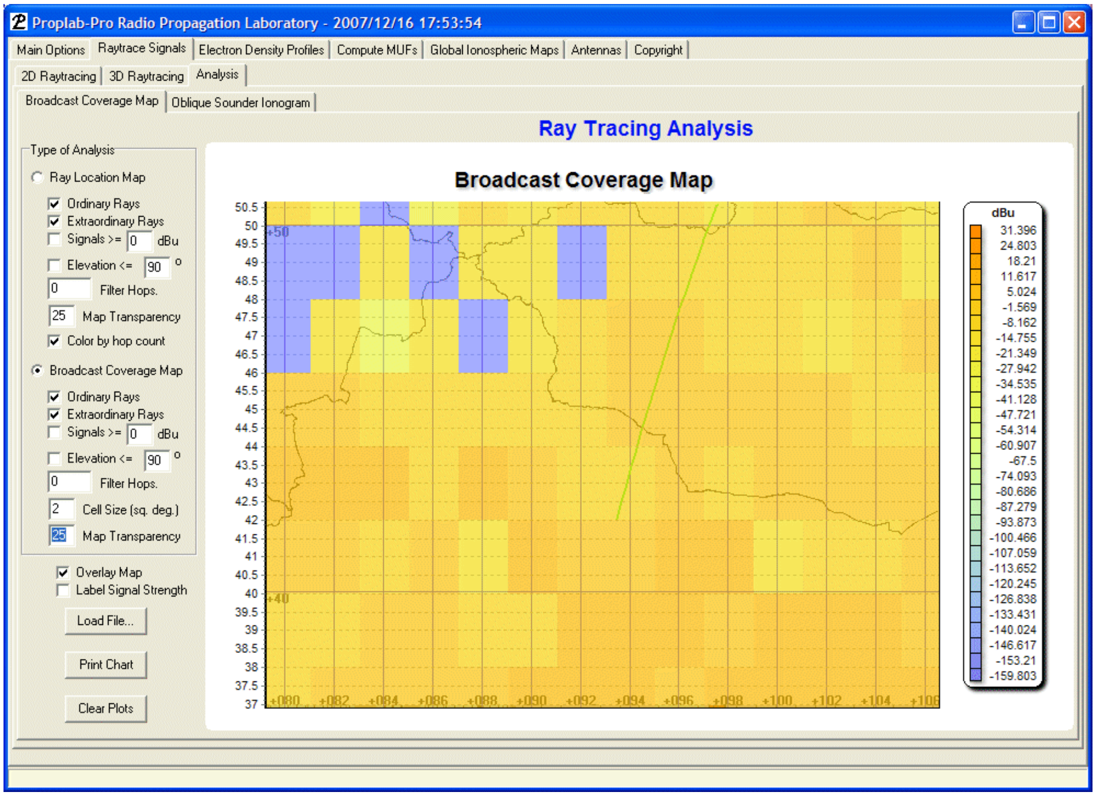


The great-circle path ends at the receiver location, which shows a box where no field strength is detected. However, remember that we're using ray-tracing, so each and every colored box represents a signal that passes close to the receiver. If we had used a smaller stepping increment in our ray-tracing phase (we used 1 degree in elevation and 1 degree in azimuth), many of these "holes" would have been filled in with signals of similar strength.

To alleviate the need of increasing resolution by ray-tracing with smaller step sizes, Proplab's Broadcast Coverage Map Analysis includes the ability to increase the size of the cells used in the display. The default cell size is one degree. By increasing this cell size to 2, we can effectively "smooth" the display so that these holes are more fully covered. In some situations, it is important to have greater resolution. Proplab-Pro (starting with Build 1003) includes the ability to map features down to 0.1 square degrees. To change the resolution, adjust the "Cell Size" box. Please note that using small cell sizes requires greater computation time. Due to memory limitations on many computers, much of the computational table is (as of Build 1003) swapped to the hard-disk. As a result, you may notice a period of heavier hard-drive usage as this chart is generated.

Proplab performs this smoothing process properly. For every signal that reaches a specific cell, the signal field strength is added to the strength of any signals that previously impacted that cell. The resulting map therefore shows slightly higher signal field strengths, but nonetheless at realistic levels. The field strength is in units of dBµV/m or decibel microvolts per meter (into a 50 ohm system).

Here is the result of increasing the cell size to 2.

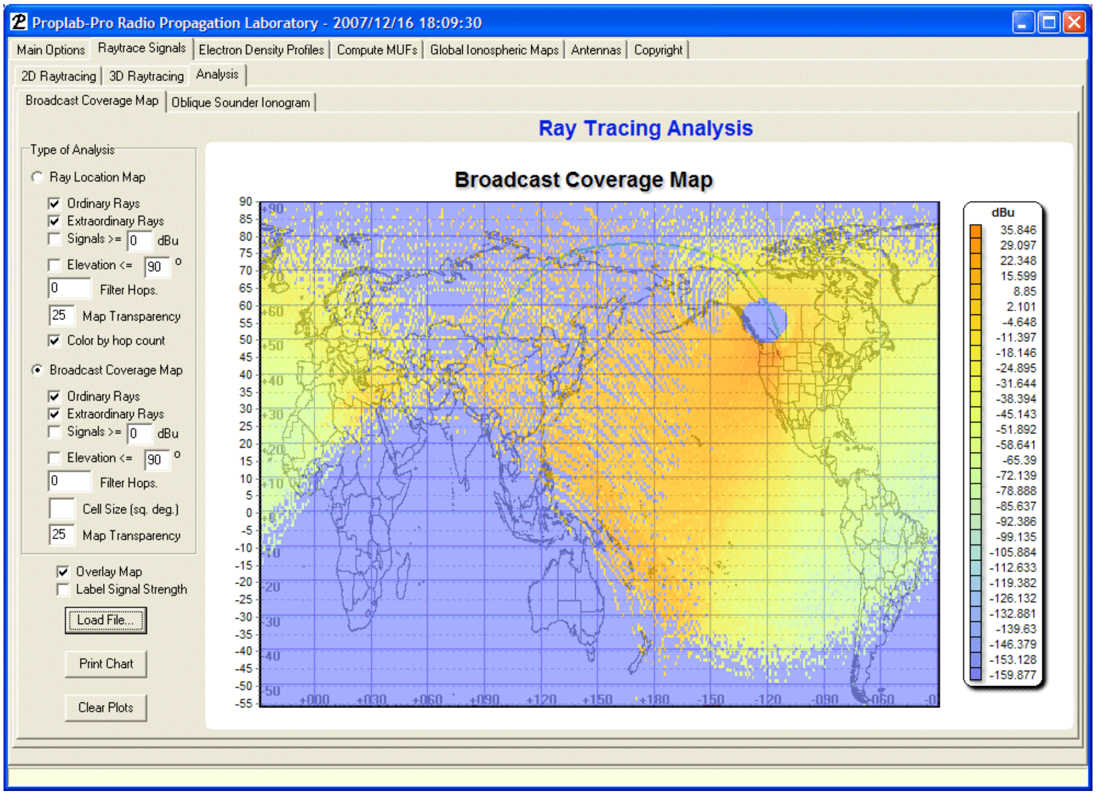


Note: The units in the legend for the above map should be dBµV/m, not dBu. This was corrected in a later version of the software.

As this operation shows, most of the area around the receiver is now properly displaying the anticipated signal field strength at the receiver. It also shows that a signal is, indeed, received, even though the main lobes of the transmitter are oriented away from this great-circle path.

So a respectably strong signal is possible to receive, assuming the local floor noise levels at the receiver permit it. Proplab does not (yet) use local floor noise levels in computing field strength.

Here is another example of what happens if, all things being equal, the transmitter antenna is rotated 90 degrees toward the west.



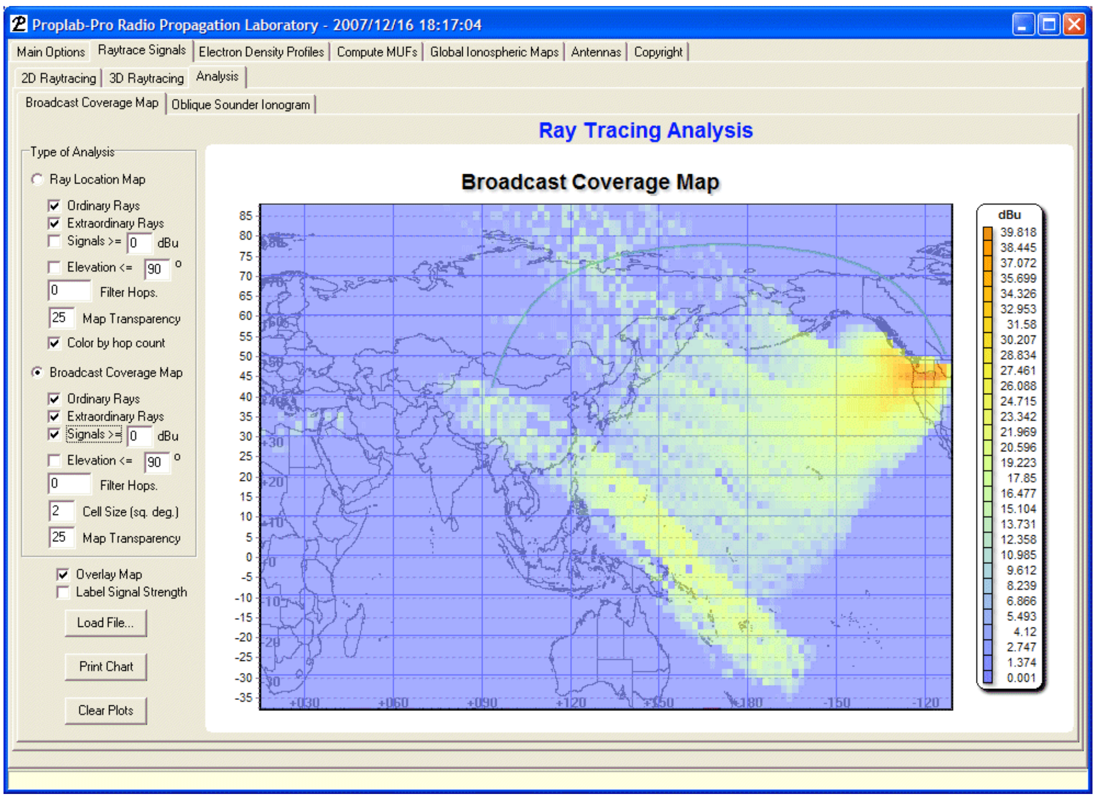
The effect is clearly evident in the increased field strength that propagates into the dark sector along the southwest.

Although not shown, if we rotated the antenna toward the great-circle bearing, the receiver would not notice a significant increase in field strength, and the coverage map would not be filled in any more dominantly toward the northwest than it is now. The reason for this is that on bearings toward the northwest, the 5 MHz signal exceeds the critical ionospheric F2 layer frequency and penetrates the ionosphere. Most of the signal field strength is therefore lost to space as wasted energy. This is why we never included that example in the present treatment.

What additional information can we glean from these analyses? To learn more, we need to perform filtering operations.

FILTERING SIGNALS

The act of filtering signals involves removing specific types of data from the database so that what we desire becomes more readily apparent. Proplab can filter signals of differing strength, differing elevation angles, differing type (ordinary vs extraordinary), and differing hop counts. There are too many screens that we could show you to demonstrate these varied abilities. What we show below is a subset of what is possible. We will use the same example as above (based on the transmitter oriented at 225 degrees, to the southwest).

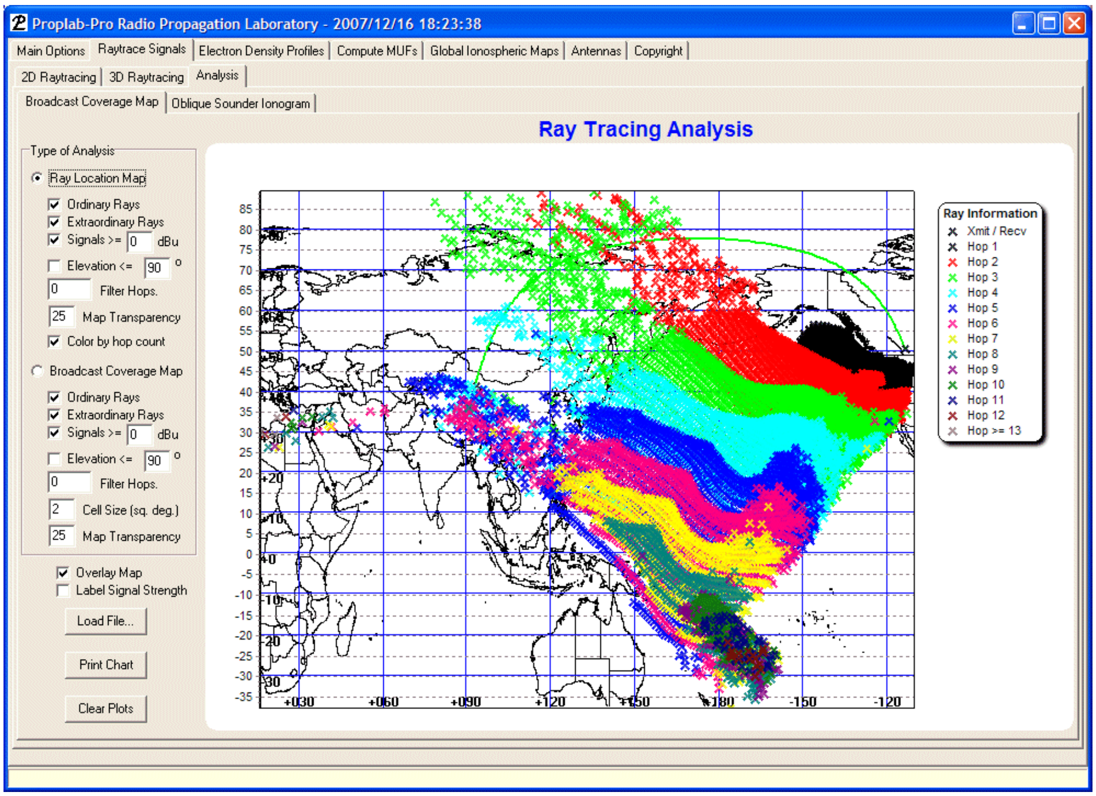


In this example, we have filtered out all signals that have field strengths of **less than** 0 dBµV/m (with a 50 ohm system). This removes a considerable number of the rays from the results. In fact, it reveals that almost all but the northwest continental United States and the southwest corner of Canada are able to receive anything with strengths above zero dBµV/m. Again, notice the impact of the skip zone as a focusing agent.

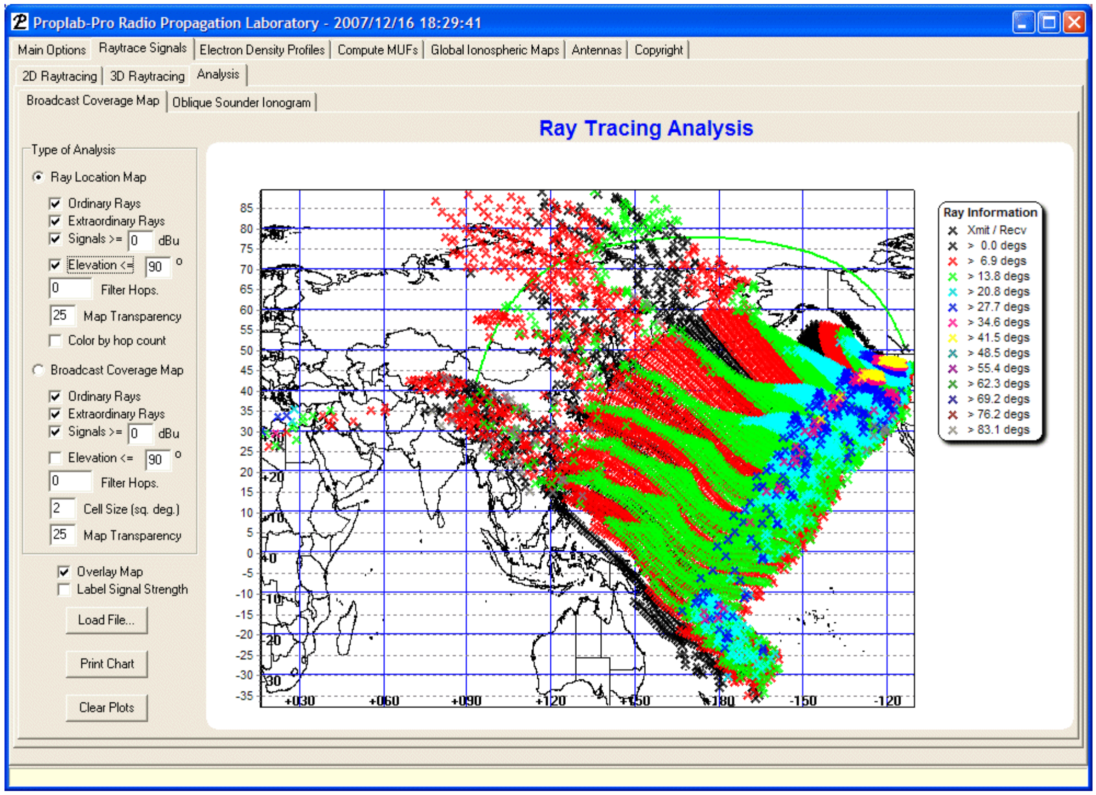
What is most interesting here is that there is a band of signals that are received from just north of New Zealand and spanning northwest from there across much of

Indonesia and into Asia where the signal field strength is notably enhanced. That is good information to know.

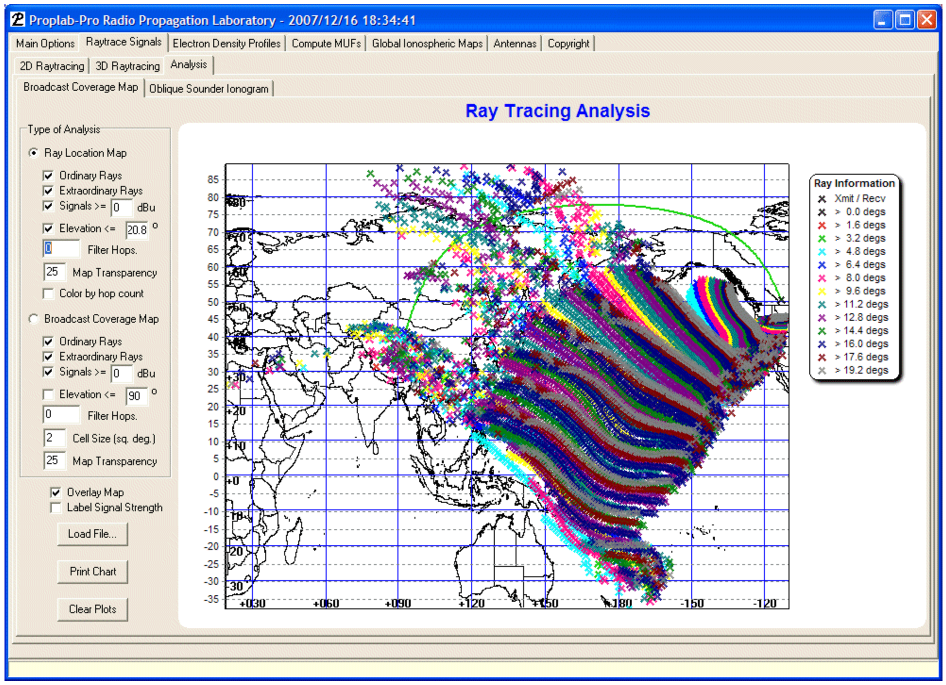
There are also striations of enhanced signal along the northwestern areas of the broadcast map, spanning from southern Alaska toward Japan. What is causing these enhancements? To find out, we turn to the Ray Location Analysis to help us figure this out.



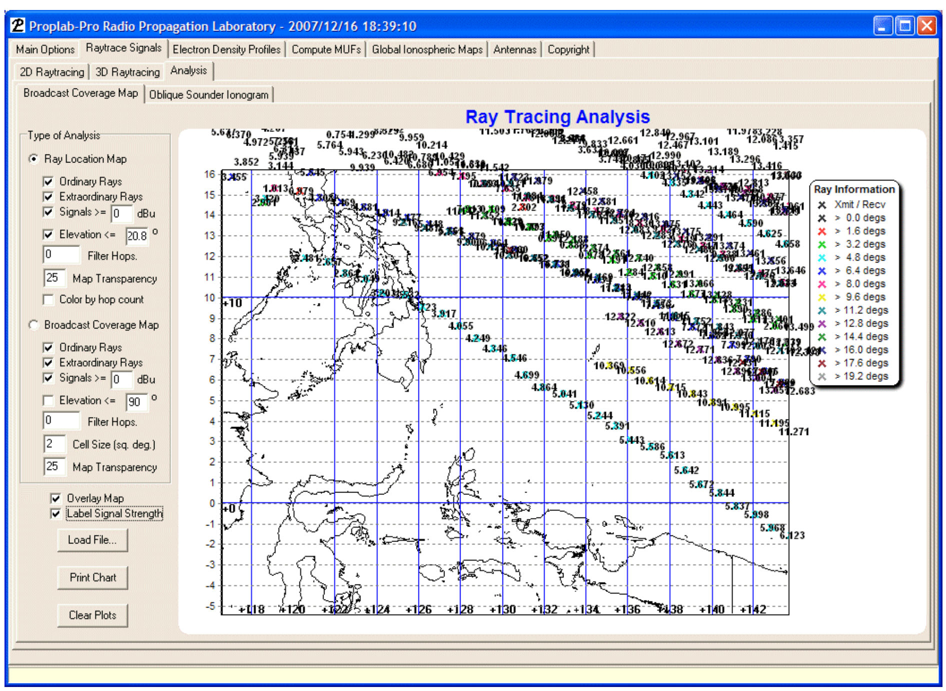
This maps is identical to the preceding Broadcast Coverage Map, except that it shows the number of hops that each signal takes. From this, we now know that signals having hop counts of 2, 3 and 4 are dominantly responsible for the striations in signal field strength from Alaska to Japan. We're also able to see that a convergence of signals that take numerous hops enhance signals from north of New Zealand and across Indonesia into Asia.



This map shows the elevation angles of the signals that are transmitted to each reception location. It is interesting to see how signals with transmitted elevation angles of greater than 6.9 degrees and less than 20.8 degrees dominate the picture. This suggests that most of the signal energy observed at ground locations is of a relatively narrow elevation angle range. Fortunately, this is within the limits of our transmitters' main elevation gain lobe.



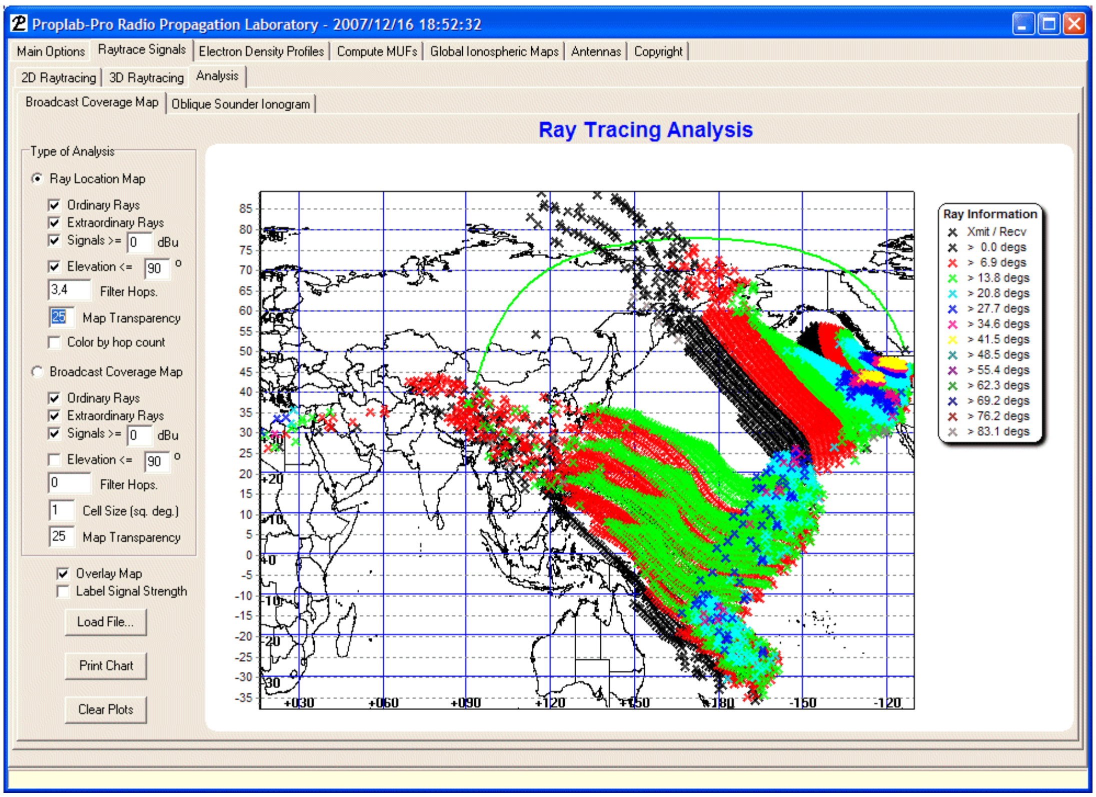
Including only elevation angles of less than or equal to 20.8 degrees, the map changes as shown. We can see that the southern-most band of enhanced signals from just north of New Zealand and through the northern reaches of Indonesia involve signals with very low elevation angles of a little more than 4.8 degrees.



We can confirm this by zooming in and labeling the field strengths for each ray.

The elevation angle map several pages back showed elevation angles of rays from zero to 90 degrees in elevation and identified them. If you look closely, you will notice that many of the rays are covered over by hops with greater counts. Each ray having a different hop count is also associated with differing elevation angles.

To help reveal these rays (and uncover them in the plot), you can filter out hops with different hop counts.

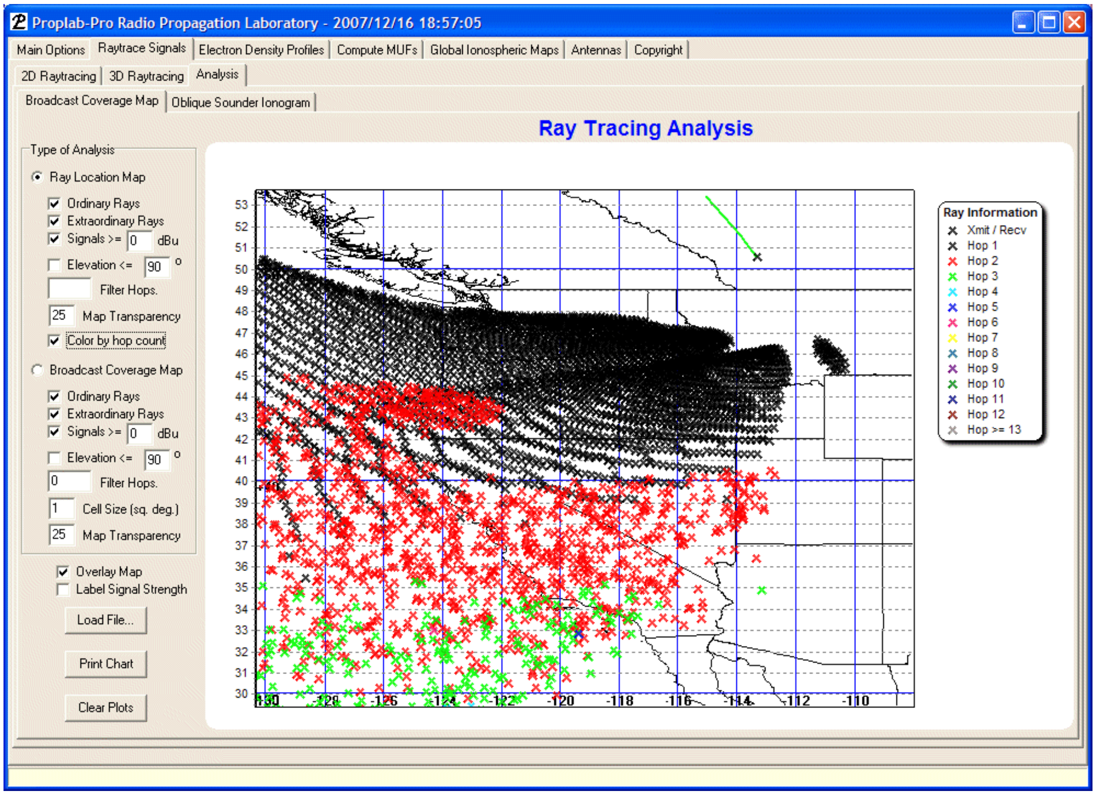


In the box labeled "Filter Hops", notice that a string of "3,4" was typed. This has told Proplab to filter out signals having hop counts of either 3 or 4.

If you compare the previous plot with this one, you will notice that many of the signals in that excluded region (particularly those with elevation angles greater than zero and less than 6.9 degrees) were covered up by those signals having hops of 3 and 4.

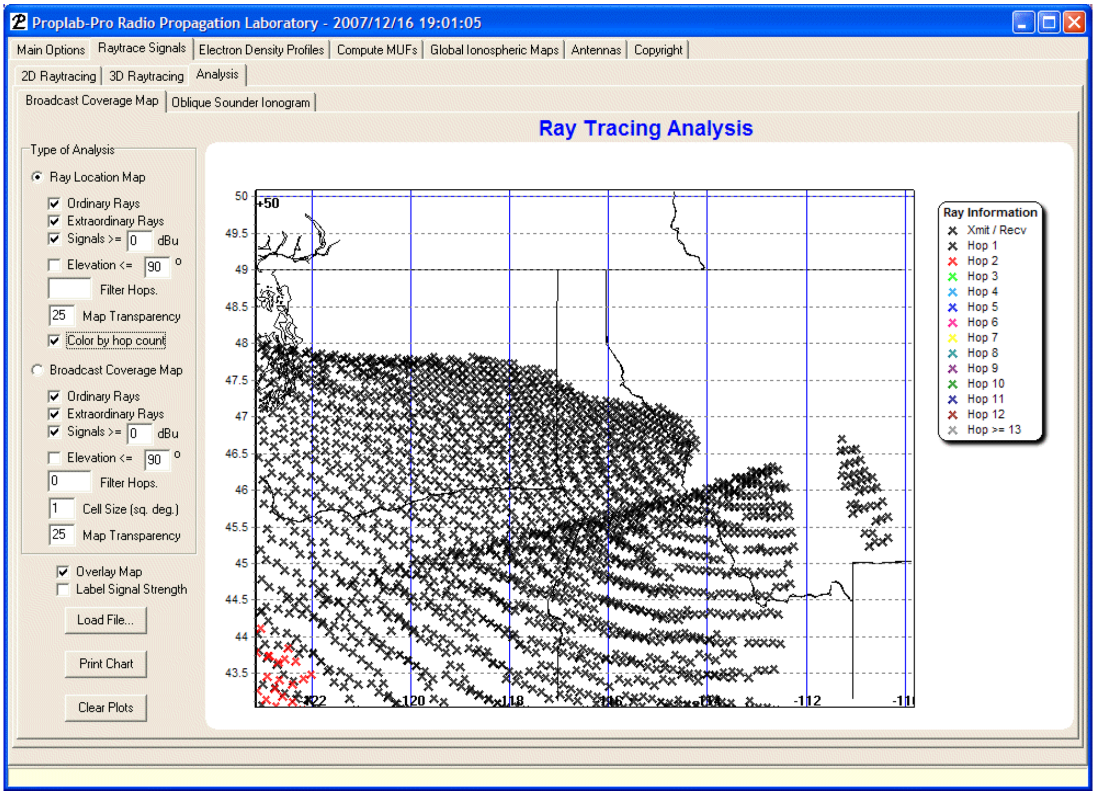
By selectively filtering out signals of specific hop sizes, you can further refine your analysis and examine details that would otherwise be hidden.

One more example is chosen to illustrate how the Ray Location Analysis can be used to identify areas of signal focusing.



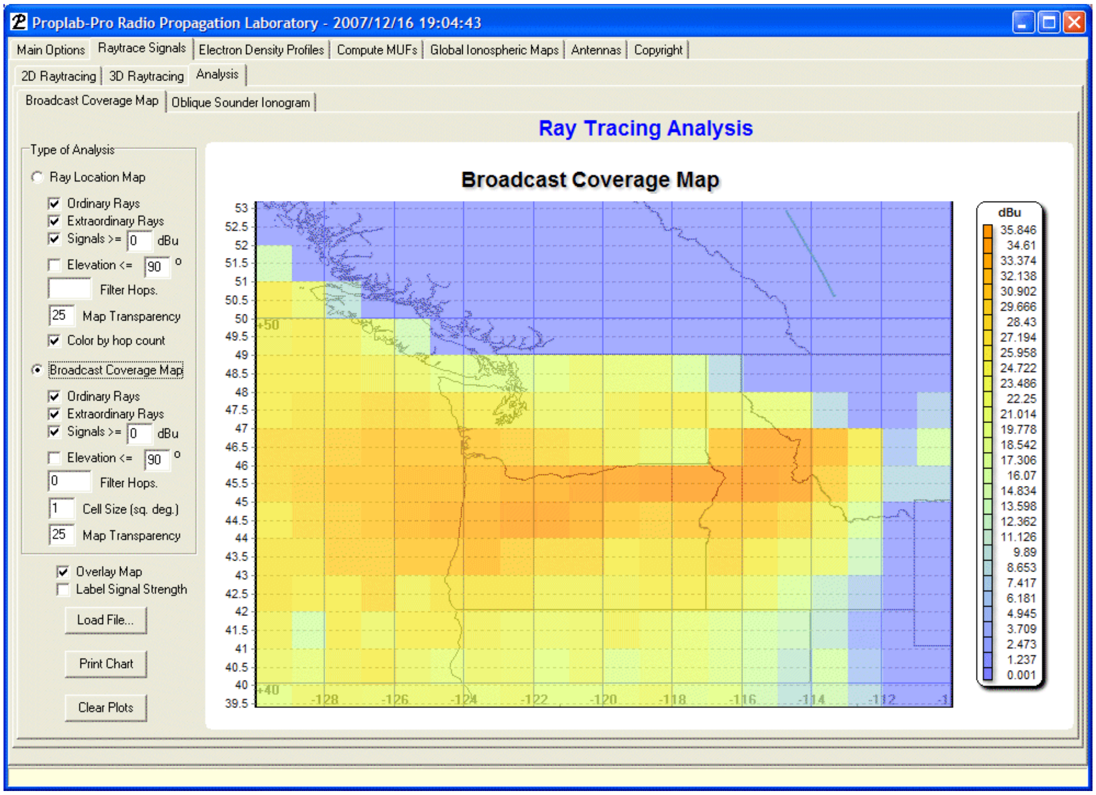
This is a zoomed in view showing signals of varying hop counts and filtered to field strengths of greater than or equal to zero dBµV/m (with a 50 ohm system) from the example above.

The closer the rays are to each other, the more focused the signals (and hence the field strength) becomes. This shows a clear enhancement in ray density near the skip zone, as well as an isolated “island” patch of enhanced density in south-central Montana. If we zoom in further, we get the following.



At this even deeper level of detail, you can see not only the area of signal focusing associated with the skip zone, but another interesting line of focusing that occurs from southwestern Montana through northern to north-central Oregon. Enhanced field strength and/or improved signal stability could be expected in those areas, at least for the snapshot in time that this ray-tracing session is valid for.

To prove that this interesting zone of focusing would indeed result in increased field strength, we present a broadcast coverage map zoomed in on that specific region of interest.



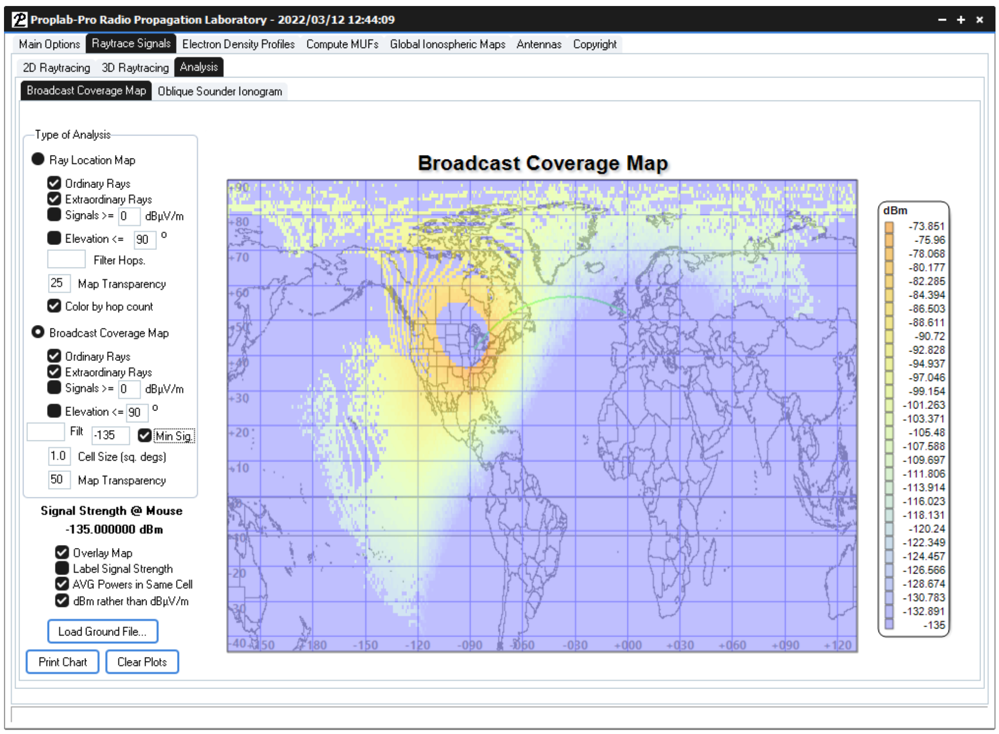
Notice that the line of focusing has indeed boosted field strength from southwestern Montana through northern Oregon. To determine what aspect of the ionospheric (or perhaps tilted ground?) reflections is responsible for that enhancement would require additional study of the signal rays themselves, which we will leave as an exercise for the reader.

The point of this is to show the power of zooming in on the results using Proplab's powerful zooming capabilities.

We think you will agree that this level of detail would be completely impossible to obtain using conventional radio propagation software. We are proud to suggest that Proplab-Pro Version 3 is unique in this respect.

SIGNAL STRENGTH & FOCUSING ANALYSIS

Version 3.2 of Proplab-Pro is uniquely capable of identifying areas of signal focusing. Take the following, as an example. A 10 MHz radio transmitter is operating using an omnidirectional isotropic antenna. It is operating near Chicago and is transmitting a little while after sunrise (at 8 am Chicago time) with a modest sunspot number. A broadcast coverage map down to the noise floor is shown below for this example.



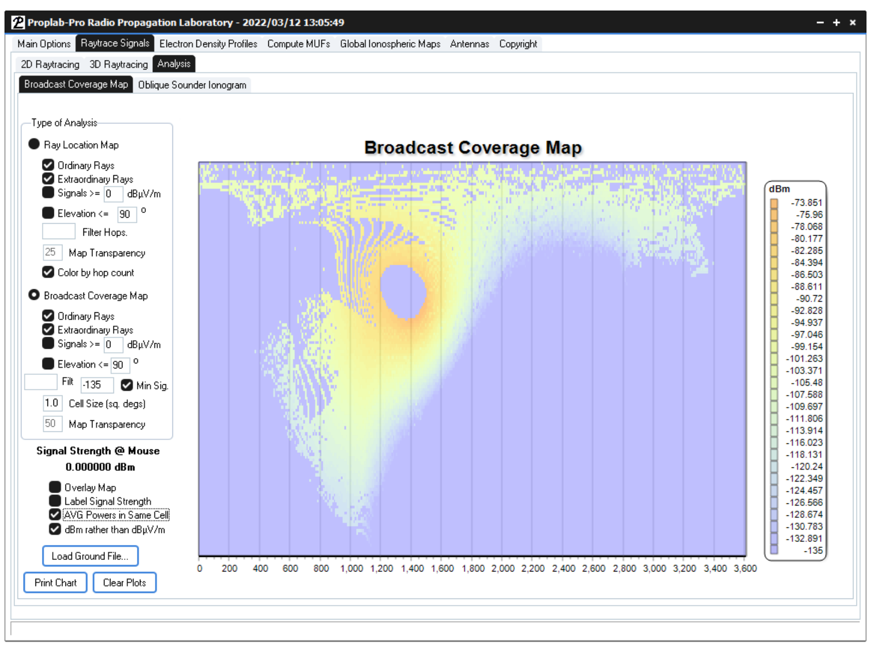
This example was obtained by saving the ground results of a ray-tracing session that varied the ray azimuth by 0.5 degrees per step in a 360 degree circle, with the elevation angle varying from 0 to 89 degrees.

Notice in the above settings that Version 3.2 contains some new settable parameters in the broadcast coverage map section. Specifically, there is a “Min Sig” checkbox and a spot just to the left of that where you can enter in the minimum signal plotted on the map. The value you plug into that box depends on whether you are displaying signal power levels in dBm or whether you are plotting field strength values in decibel microvolts per meter. If the “dBm” checkbox at the bottom is checked, then the value in this box is expected to be in dBm. Otherwise, it is expected to be in decibel microvolts per meter. Using this, you can eliminate entire slices of ray-tracings that are below the noise floor. The noise floor can be calculated in the Antenna section based on your desired signals bandwidth.

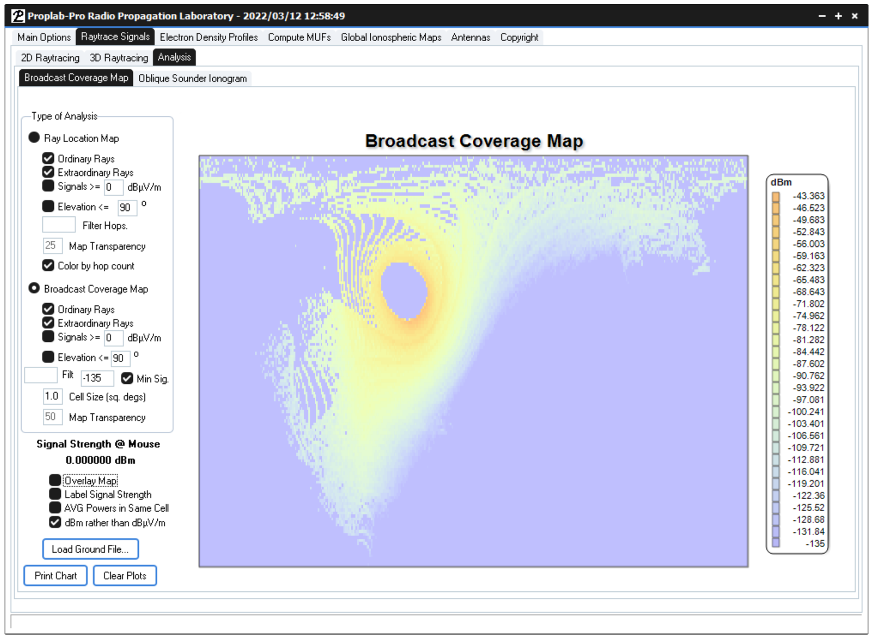
Also note that in the above analysis that we have checked the “AVG Powers in Same Cell” checkbox. In prior versions of Proplab-Pro, when two signal rays hit the ground at similar locations, the powers of those signals were added together so that signal focusing could be taken into account. However, this can artificially elevate the strength of the signal and can result in inconsistent results depending on the size of the cells used in the analysis. To correct this, the AVG Powers checkbox looks at the average overall signal strength in the area where a ray hits the ground, rather than adding the powers together. This tends to reduce the signal strength in broadcast coverage maps to levels that are more realistic.

However, using the AVG Powers checkbox also has an unwanted effect: it smooths out the mapped signal powers and makes it harder to identify zones where signal focusing has occurred. For this reason, we have maintained the prior behavior of adding powers rather than averaging them, in order to spot those areas where signal focusing is occurring.

To compare the map above with the results when the AVG Powers in Same Cell checkbox is not checked, let’s first plot the above results without the superimposed map.



And now, let's compare the above map with the un-averaged map below.

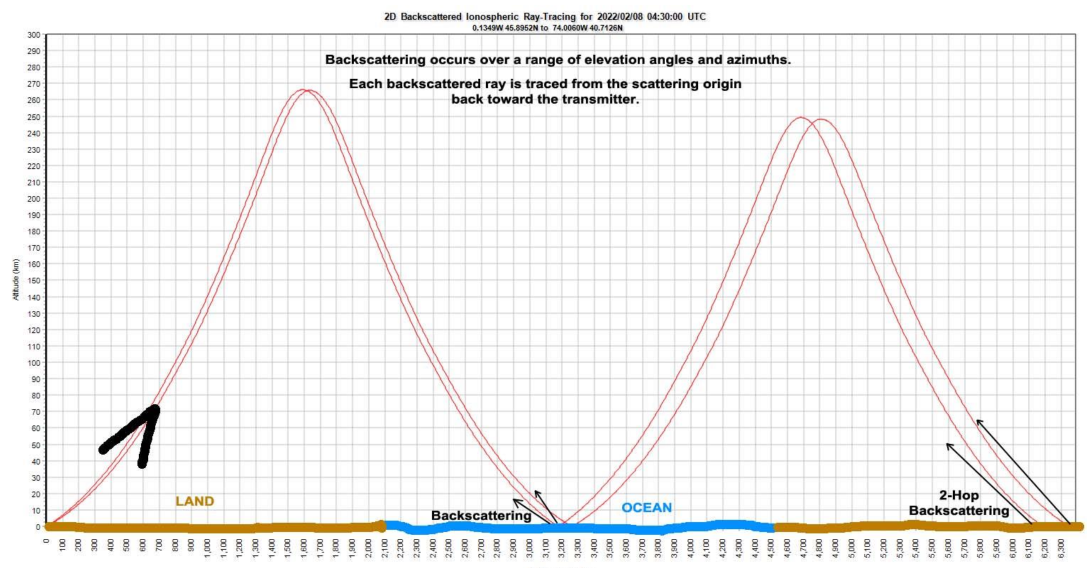


We have intentionally turned off the map overlay so that the regions of signal focusing are more clearly visible as the darker concentric rings. Those areas of signal focusing are real. But the displayed signal power levels are, in reality, probably not as high as the above un-averaged map indicates they could be. For a more realistic determination of signal strength, examine the map when the AVG Powers in Same Cell checkbox is checked and expect signals to vary somewhere at or higher than those levels near regions of focusing.

BACKSCATTER ANALYSIS

A major new function of Proplab-Pro that first became available in Version 3.2, is the Backscatter Analysis feature.

Backscatter occurs when signals are reflected from non-uniform objects like rocks, trees and ocean waves. When the forward propagating signal reaches the ground, the signal is reflected according to whatever object(s) the signal encounters at the ground. For backscattered signals, the object produces a reflection back toward the transmitter.

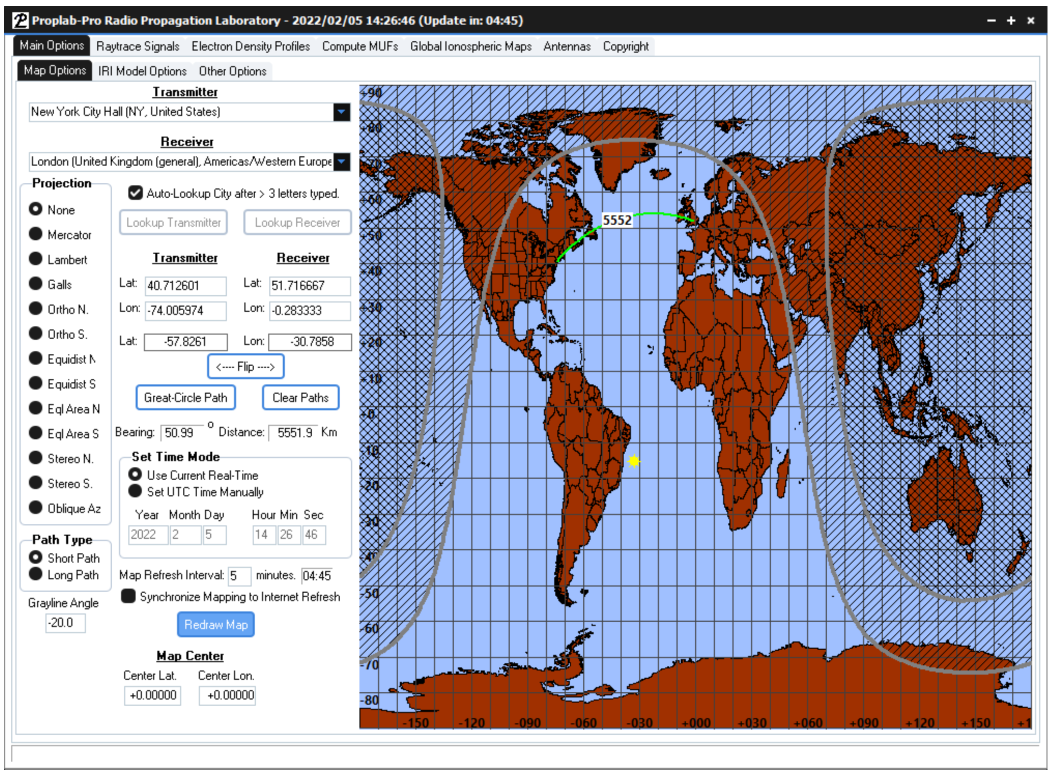


That backward reflection consumes a fraction of the energy that is reflected forward toward the receiver. As a result, backscattered signals are usually much weaker, washed out, and/or variable in nature. In many cases, the backscattered signal may be lower than the background noise and will not be detectable. However, using Proplab-Pro, an evaluation of the backscattered signals can be estimated over a range of user-selectable scenarios.

Ray-tracing backscattering is a computation-intensive process. For every signal that experiences a ground-bounce, a plethora of new signal rays must be created that travel back toward the transmitter. Proplab-Pro makes this process relatively simple, although it may still consume a fair amount of time.

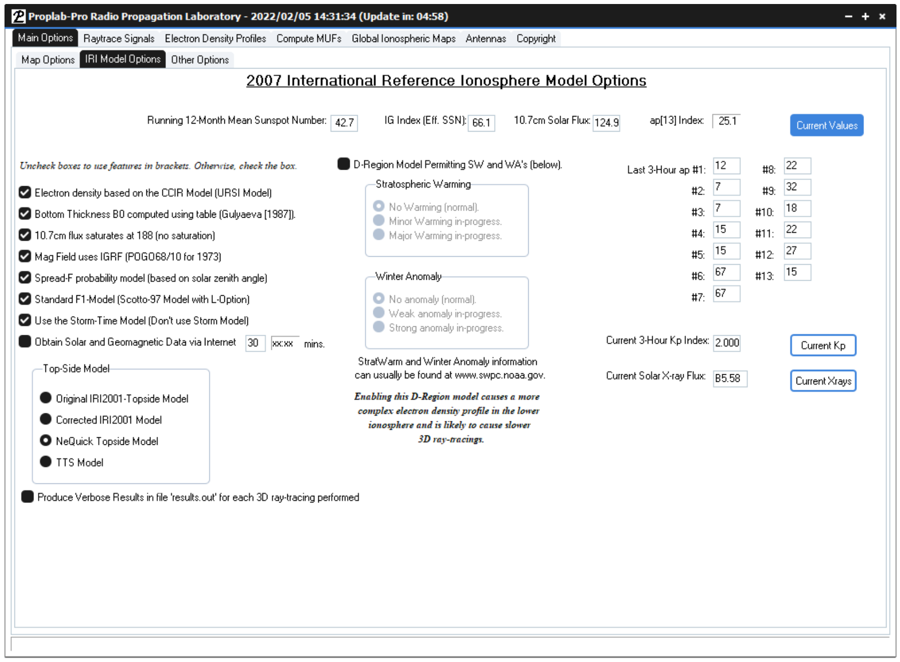
Currently, Proplab-Pro only supports two-dimensional back-scatter analysis. Three-dimensional ray-tracing analysis of backscattering would normally only slightly improve the analysis accuracy during times of sunrise or sunset, when ionospheric tilts might affect the results. The cost would be prohibitively long computation times. For most other times of the day, the ionospheric layers are flat enough for these effects to be ignored. As such, the two-dimensional analysis should be sufficient in the vast majority of scenarios.

To explain how to perform a backscatter analysis, we will consider an example where a 5 kW transmitter is located in New York city and the receiver is in London as shown below.



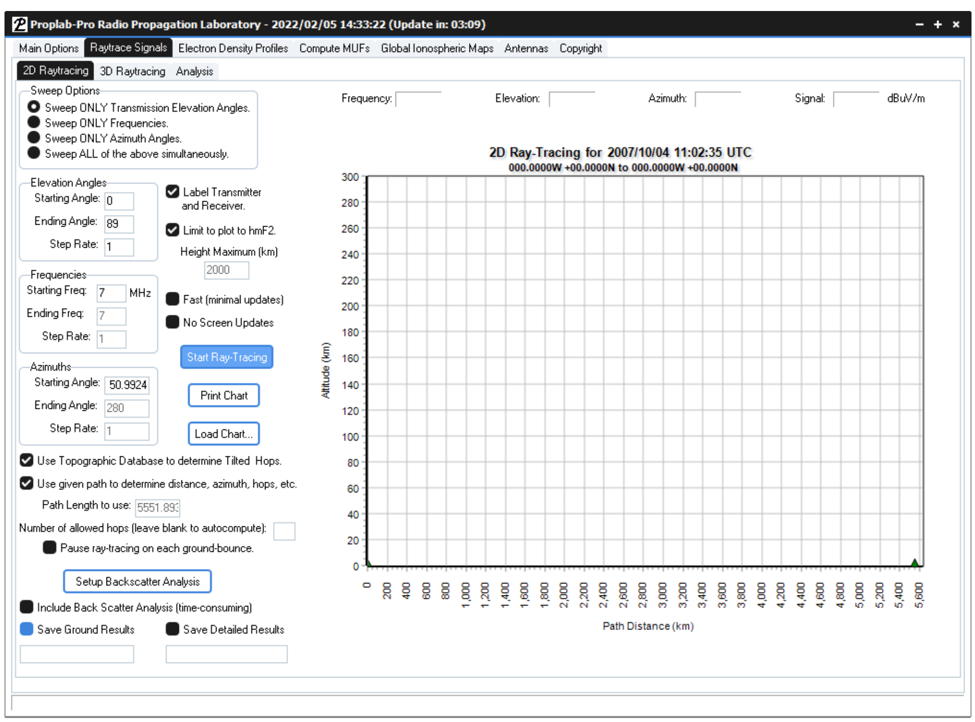
The first step to performing a backscatter analysis is to identify the desired circuit as shown above.

The second step is to make sure that the ionospheric parameters are all set properly.



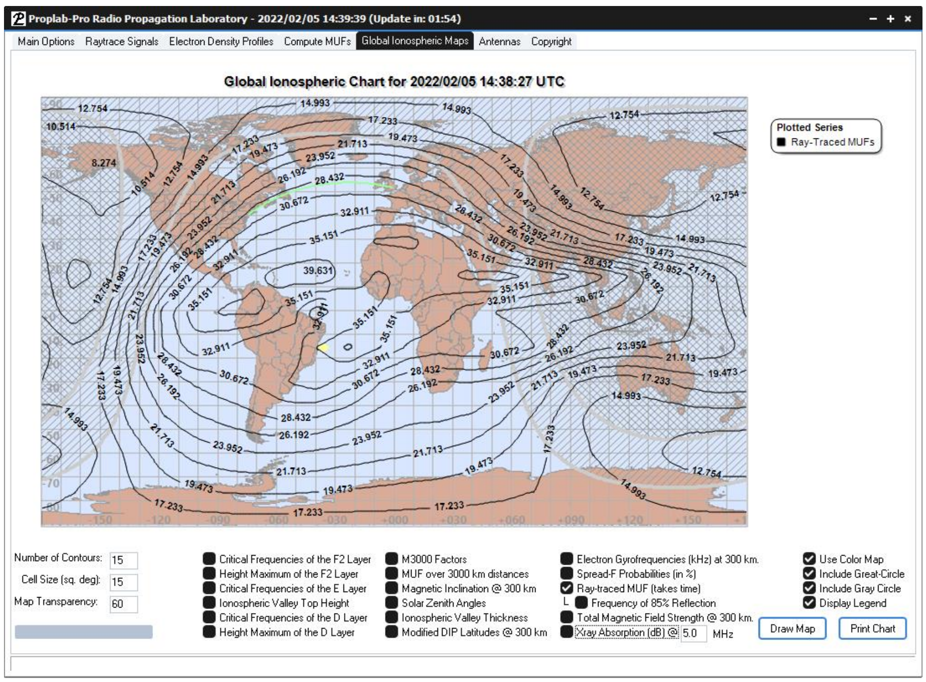
We click the Current Values button to obtain the latest geomagnetic and solar information so that the international reference ionosphere has sufficient information to build a realistic ionosphere through which we can perform ray-tracings.

Once this is done, we select the 2D ray-tracing tab and start setting that up.



In our scenario, we would like to examine the signal characteristics around a 5-degree azimuth centered around the New York to London azimuth. As the above screen shots indicate, the azimuth is 51 degrees. So we would like to analyze not only the signal properties of the signal that reaches London, but we also would like to examine the properties of the signal +/- 2.5 degrees from the 51 degree azimuth. In addition, we would like to see all transmission elevation angles from 0 degrees (horizontal) to 89 degrees (vertical).

If we perform a Global Ionospheric Chart computation of ray-traced maximum usable frequencies for this selected path, we see the following.



This indicates our MUF should be near 28 MHz. Let's choose a frequency a little lower to ensure that our signal gets there without significant attenuation, since this is a daylight path. Let's use 15 MHz as our transmitter frequency.

We don't want to vary the frequency in our ray-tracing analysis, but we do want to vary both the elevation angles and the azimuths. So we select the "Select All of the Above Simultaneously" option from the 2D ray-tracing menu. We also set the frequency to 15 MHz and we set the power of our transmitter (in the Antenna tab) to 5000 watts. Additionally, while we are on the antenna page, we select an isotropic antenna for both the transmitter and the receiver, although you could use any of the antennas available (or create your own).

Back in the 2D ray-tracing tab, we set the starting azimuth to be 2.5 degrees less than the indicated bearing to London and the ending azimuth to 2.5 degrees greater than the indicated bearing. We also set the azimuth step rate to 1 degree so 5 ray-tracings should be performed for this path on varying azimuths.

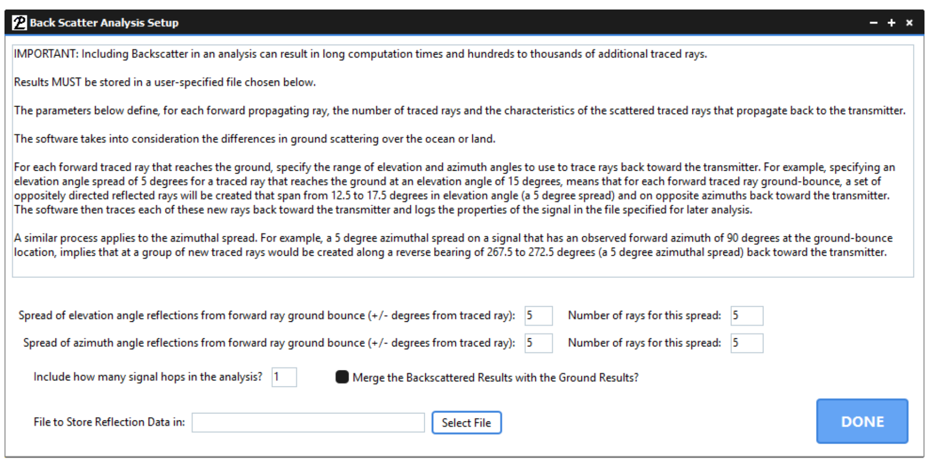
Next, we set the elevation angle range from a starting angle of 0 degrees to an ending angle of 89 degrees and a step rate of 1 degree.

Our 2D ray-tracing setup is now complete, but we have not yet instructed the software to perform an additional backscatter analysis.

To do this, we must check the box that reads "Save Ground Results." Backscatter analysis cannot be performed without this. When you check this box, you will be asked to select a file to store the ground results to. Choose a file or name a new file that doesn't exist and the software will create it.

Next, click the button "Setup Backscatter Analysis."

This will open a new dialog window as shown below.



Read the information in the box to understand how to fill in the information on this page.

Set the spread of elevation and azimuth angles that you would like to analyze, as well as the number of rays to represent each of the elevation and azimuth angle spreads. We will leave the system set to the defaults above.

What this tells the software to do is to generate new rays to be traced from each of the **first** ground bounces that occur in our transmission, back toward the receiver. The azimuth and elevation angles for each of these new ray-tracings will span 5 degrees, centered on the observed azimuth and elevation angles that are **observed at the ground-bounce location.** There will be 5 ray-tracings created in elevation angle that are centered around the observed elevation angle of the ray at the ground-bounce location. And there will be an additional set of 5 ray-tracings created that span 5 degrees of azimuth at the location of the ground bounce, but the trajectories of these rays will be **back toward the transmitter.** In total, our example above will create 25 new ray-tracings for each ground-bounce of the main signal towards London. But this will be applied to only the first ground-bounce, since we have specified that only 1 signal hop should be included in the analysis. If we had specified 2 signal hops, then 2 x 25 (or 50) total ray-tracings would be created covering the first and second ground bounces toward London.

As you can see, the number of ray-tracings required to complete a solution depends heavily on how you set up this section. For most backscatter analyses, a single hop is sufficient.

If the "Merge the backscattered results with the ground results" checkbox is checked, Proplab-Pro will perform all of the required forward and backscattered ray-tracings, and then store ALL of the results in the ground file specified earlier, as well as storing just the backscattered signal analysis in the backscatter file (see below). This is a handy way to get an overall view of signal propagation, including backscatter analysis, since both the forward propagating analysis as well as the backscattered propagation analysis will be displayed. NOTE, however, that there is no way to distinguish backscattered results from forward propagated results when this checkbox is selected and you view the data in the Analysis tab.

If the "Merge" checkbox is Unchecked, the forward propagated ray-tracing results will be stored in the ground file specified earlier and the backscattered results will appear in the backscatter file specified below. By unchecking this box, you can keep the two analyses separate.

Finally, click on the "Select File" button and select a file to store the backscattered information into. Note that this file is different from the ground results file, as described above. Both are needed for Backscatter analysis to work. Specify a new file if you want to store the results in a new file.

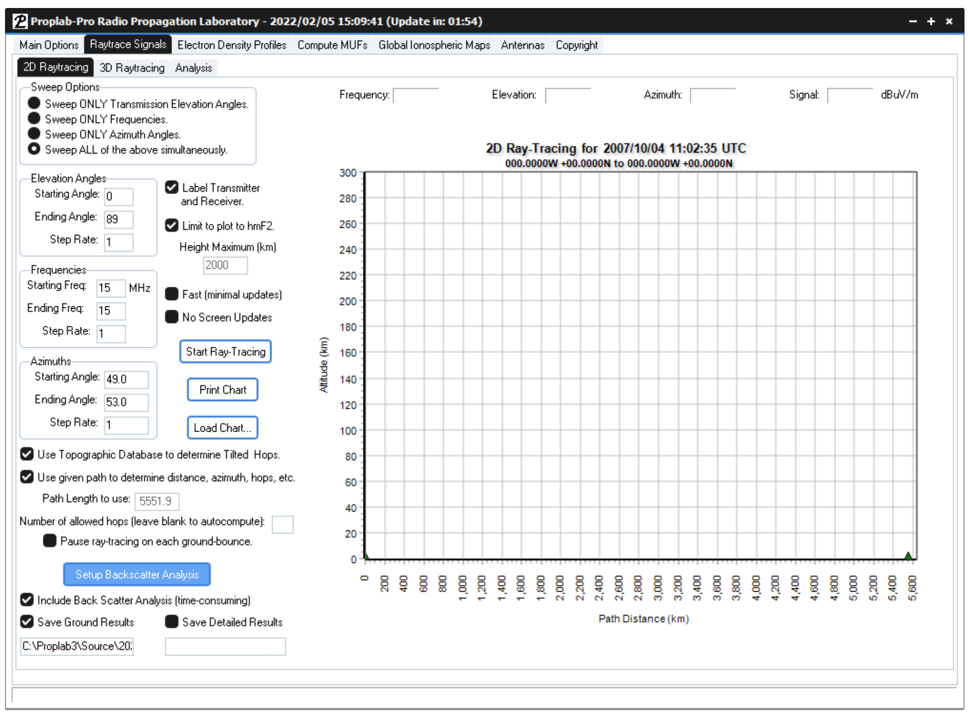
After you select the file, click the DONE button. A warning will then be displayed.

The software computes the maximum number of possible rays that might need to be computed to arrive at a backscattered solution. The above scenario suggests that as many as 13,500 individual rays may have to be computed. The dialog box asks if you are ok with this. If you aren't, click Cancel and change the parameters of the backscattered ray-tracing setup window to something less demanding.

Note that on most modern computers, the above 13,500 ray-tracings will not take too terribly long to complete.

For much more intensive analyses, the speed can be drastically improved by clicking on the checkbox "No Screen Updates" on the 2D ray-tracing tab. This will force Proplab-Pro to avoid displaying each of the traced rays and instead the software will simply compute the rays internally, saving considerable time without sacrificing accuracy.

Our setup now looks like this.



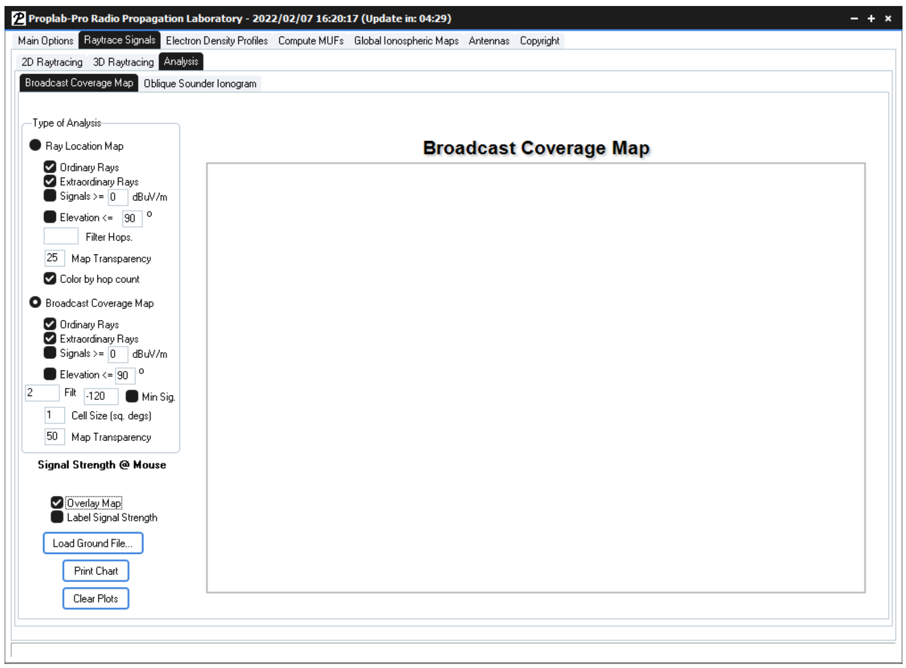
We are now ready to click on the "Start Ray-Tracing" button.

This is a two-step process. First, Proplab-Pro ray-traces each signal as it travels to London from New York, on every elevation angle and azimuth specified. The results are stored in the ground results file specified.

Once that phase is done (which doesn't normally take very long), the more time-consuming backscatter analysis is started. You will notice when this phase begins. The prior ray tracings will be erased and a new set of ray-tracings will quickly fill the screen. If you look closely, you will notice at the top that the latitudes and longitudes of the ray-tracings changes, and a message will appear at the bottom of the software in the Status Bar area announcing that backscatter analysis is in progress.

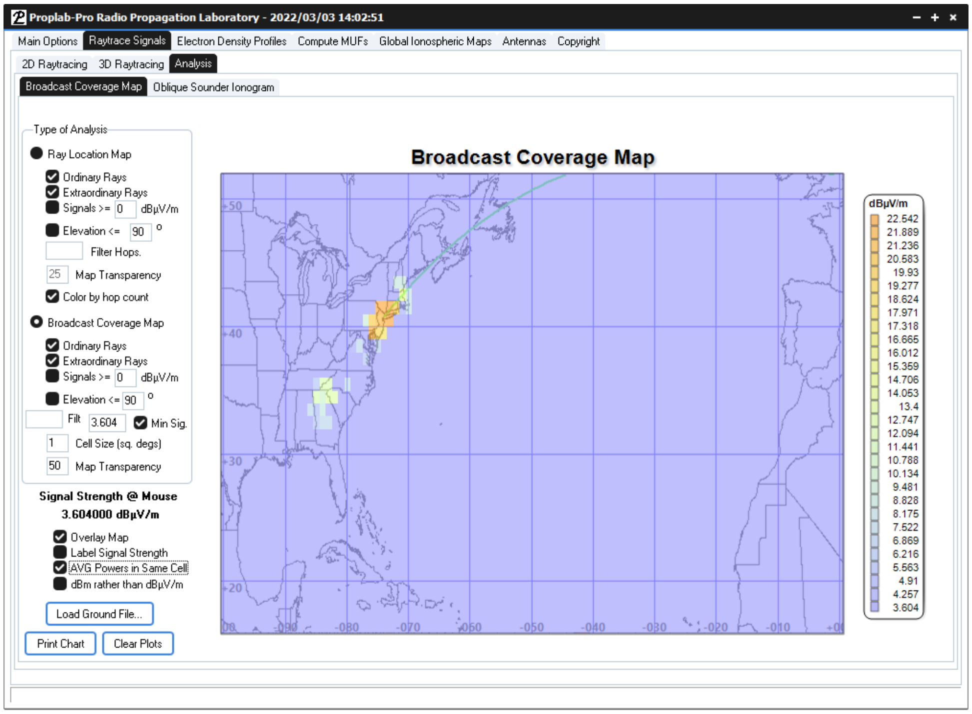
Again, you can speed up the completion of the analysis by clicking on the “No Screen Updates” checkbox. When you do this, the upper-right section of the software will continue to be updated according to the current elevation angle and azimuths being ray-traced, but you will not see any plots on the screen.

After the analysis is complete, you can display the results by going to the “Analysis” tab.



Now we can use the “Load Ground File…” button to load our backscatter analysis (or the ground results analysis) into the system for display. Note that the ground analysis file we specified in the ray-tracing tab contains only the forward propagating solution and the backscatter analysis file that was set up in the backscatter setup section only contains the backscattered analysis. You can therefore evaluate each separately. Or, you can combine the two analyses in the ground-analysis file if you check the “Merge” checkbox in the backscatter setup dialog.

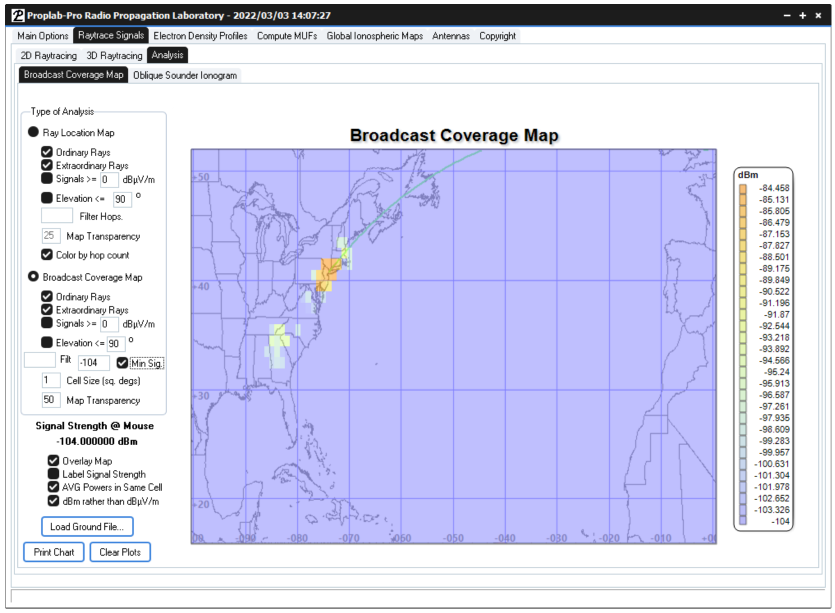
We have specified above that we wish to see the broadcast coverage map of the backscattered signals.



The results above indicate that there is a fairly large area along the east coast of the United States where it might be possible to pick up the backscattered signal. Note in the legend on the right that the minimum signal level plotted is about 3 dB microvolts per meter, which is near the noise floor.

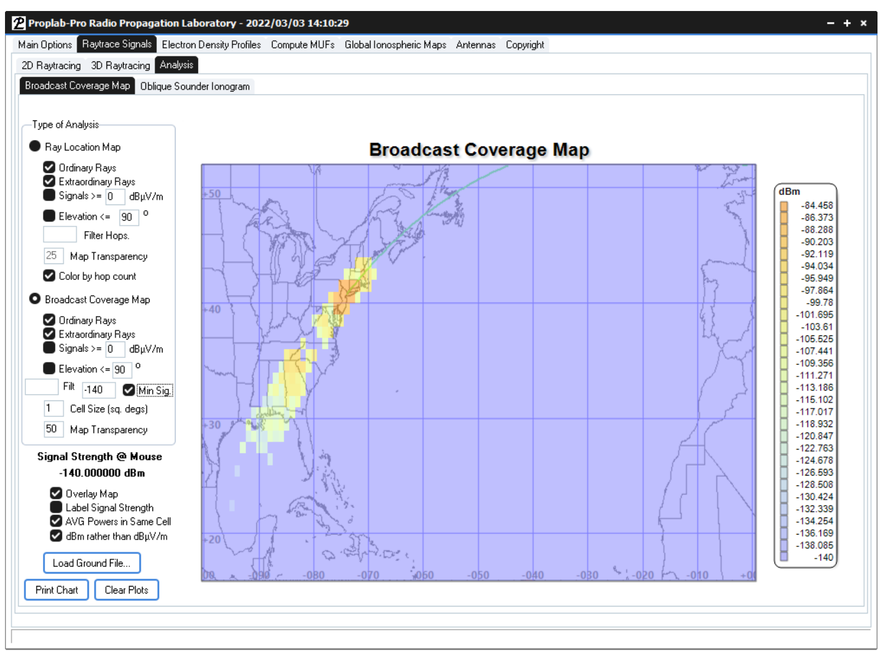
You can convert the indicated signal field strength to units of dBm by subtracting 107 from the indicated dBμV/m value: dBm = dBμV/m – 107. So a field strength value of 3 dBμV/m is equivalent to -104 dBm.

Or, you can click on the “dBm rather than dBμV/m” checkbox to redisplay the results in dBm as shown below. Note that when you click this checkbox, you might need to adjust the minimum plotted signal field strength to a dBm value as well, if that is enabled. Below, we are plotting all signals with a strength greater than -104 dBm, which again is near a realistic noise floor.



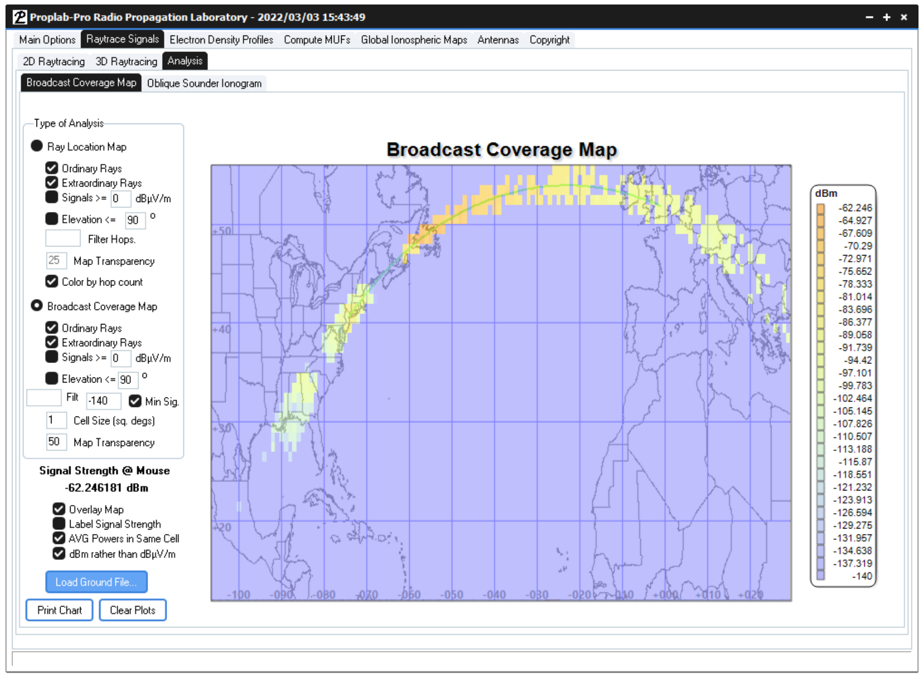
The absolute theoretical noise floor is closer to -140 dBm (you can determine this yourself in the Antenna tab by setting the bandwidth at the bottom of the page).

You can adjust the field strength level by changing the value of the "Min Sig" box and then checking check-box. If we don't limit the field strength values, we end up showing all of the signals, including even the weakest signals that are infinitely below the noise floor. If we change the minimum signal value from -104 to -140, we can see much more of the signal that is backscattered.

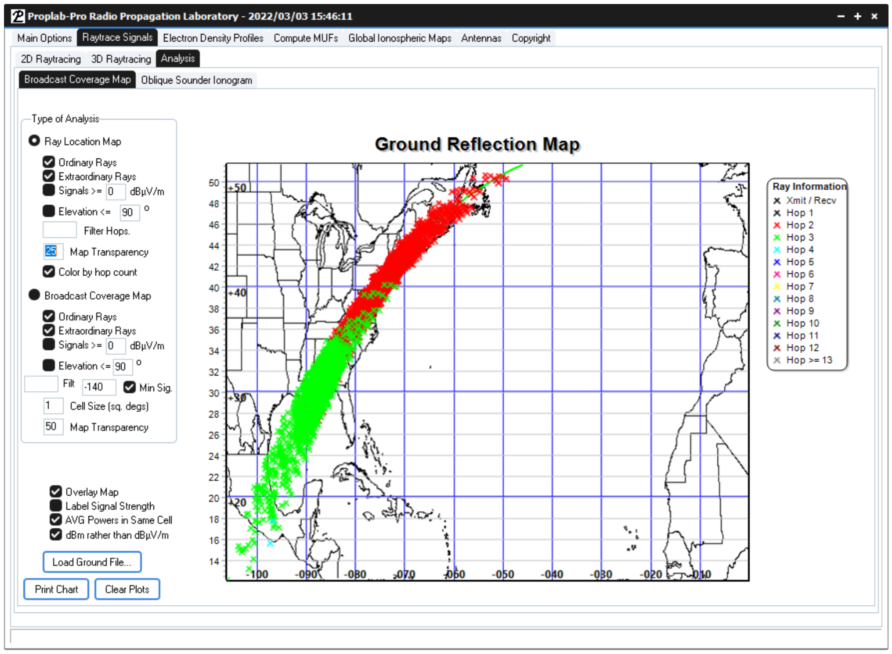


Moving the mouse over the region allows you to inspect the value of the cells on the map.

If we check the box that merges the backscatter analysis with the ground-based analysis, we get an overall view of our signal as shown below.



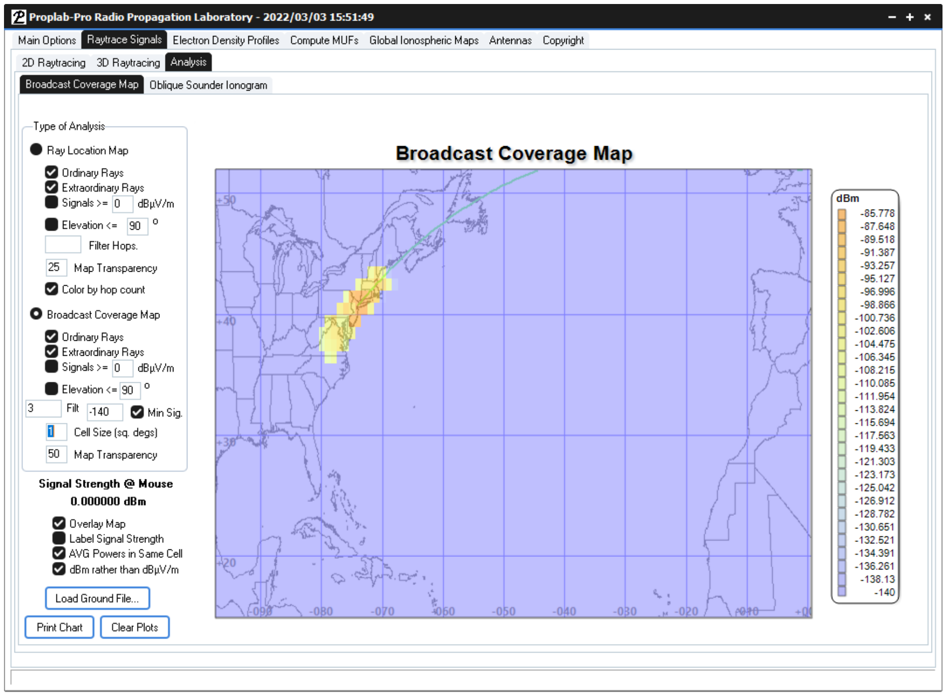
Looking at the Ray Location map reveals the locations of the first and second hops of the backscattered signal (below).



The color above represents which rays hopped once or twice from the backscattered region. NOTE: The legend says "Hop 3" is in green, but this is the second hop AFTER the signal was backscattered. The backscattering counts as one hop, so in reality, the signal has actually bounced from the ocean/ground three times since leaving the transmitter. So the chart above is correct for two backscattered bounces.

There are even a few signals that hop three times from the backscattering location (colored as "Hop 4" above).

We can filter out those second hops from the broadcast coverage map results by setting the Filter box to "3" (which means, exclude signals that hop three times, or twice from the backscattering region). The map below excludes the forward propagating signal and just examines the backscattered signal.



As expected, the region of highest backscattered signal field strength maps back to the area around our transmitter, since the radio path is fairly stable and supports two-way paths.

Note that Proplab-Pro will handle ocean backscatter differently than land backscatter. And if you check the "Use Topographic Database to Determine Tilted Hops," it will use the terrain database to help determine ray trajectories from tilted terrains. Ocean backscatter is generally stronger than land backscatter. NOTE: If the checkbox "Use Topographic Database to Determine Tilted Hops" is not checked, all ground and ocean bounces are assumed to be from the land, even if the rays are scattering from an area that is the ocean.

Also, note that Proplab-Pro will not compute line-of-sight backscattering of signals, such as for over-the-horizon (OTH) HF radars. Only signals that include at least one ionospheric reflection are analyzed, and as such, the analysis is limited to sky-wave backscattering.

Finally, you can use your mouse to determine the signal field strength over the broadcast coverage maps. By holding the left mouse button down and dragging your mouse to the lower-right, you can draw and zoom into a rectangular area of the broadcast coverage map for better clarity of particular features. To undo the zoom, left-click and drag to the upper-left.

It is important to remember that backscattered signals use the antenna setup a little differently than in the normal forward-propagated ray-tracing analysis mode. During normal ray-tracings, the azimuth of the receiving antenna will naturally be quite different from the azimuth of the transmitting antenna.

With backscattering analysis, the receiving antenna is usually co-located with the transmitting antenna (they are often one and the same when acting as radar backscatter). So to properly set up a radar backscatter scenario, the transmitting and receiving antenna azimuths should not be locked (in the Main Options tab). The receiving antenna azimuth should then be set to the same azimuth as the transmitting antenna if the analysis is for an HF sky-wave backscatter radar. This will give more appropriate results that takes into consideration both the transmitter and receiver antenna gains. However, it is important to understand that in this situation, EVERY POINT where a backscattered signal reaches the ground will be assumed to be at a receiving antenna, so receiving antenna gain will be applied for every location where a ray touches the ground after being backscattered. This will result in unrealistic broadcast coverage maps, except immediately around the transmitter.

To produce more realistic broadcast coverage maps of received backscatter signal power, use a realistic transmitter antenna, but set the receiver antenna type to isotropic (zero gain) so that every backscattered ray that reaches the ground does not have any antenna gain applied to it, aside from what the transmitting antenna produced.

THE OBLIQUE SOUNDER IONOGRAM

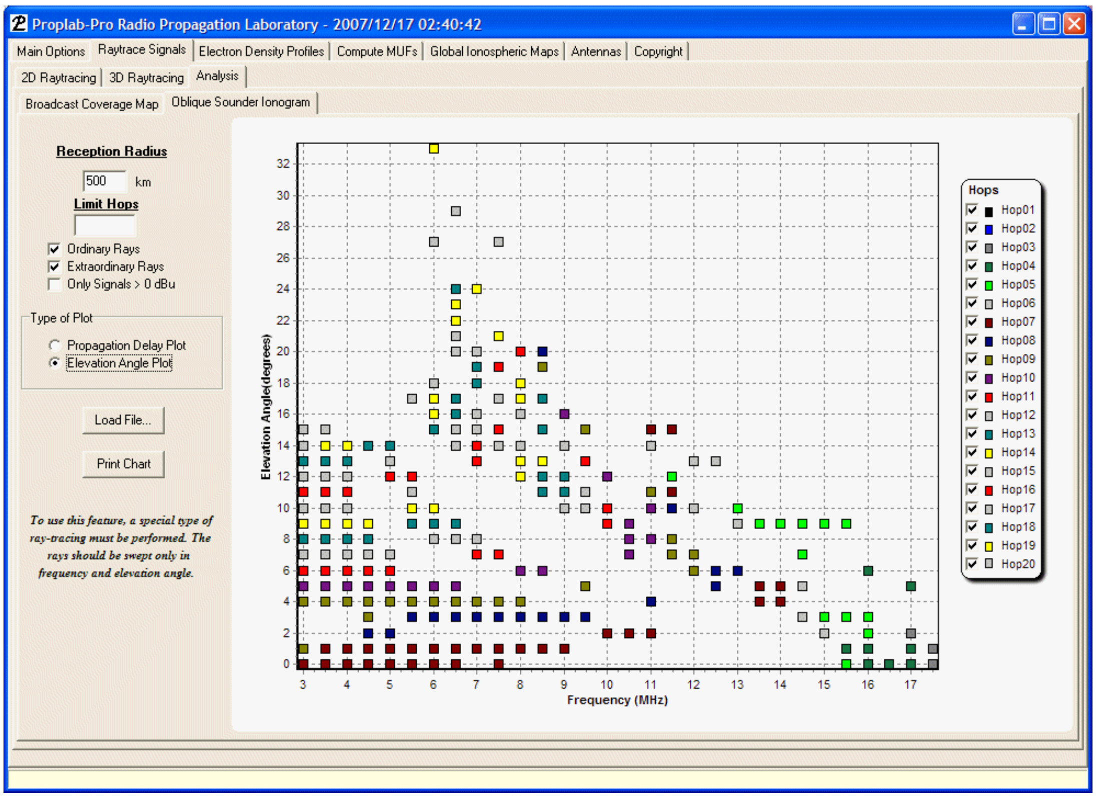
This feature of Proplab-Pro will perhaps be used less frequently than the Ray Location and Broadcast Coverage Maps features. But it is nonetheless capable of providing valuable information about the behavior and characteristics of ionospherically propagated radio signals.

The title of this feature, although a bit obtuse, is named after the soundings made by oblique ionospheric sounders, because the results it presents are of the same style. Those instruments are able to measure the propagation delay and other characteristics of obliquely propagating radio signals.

In order to perform this type of analysis, a specific type of ray-tracing session must be performed first. During that session, signals must be swept in both elevation angle **and** frequency, but not in azimuth. What we are doing is mimicking the oblique sounding ionogram instrument, which sends out pulses of radio energy at varying frequency and elevation angle, toward a target that will measure the obliquely reflected ionospheric echoes.

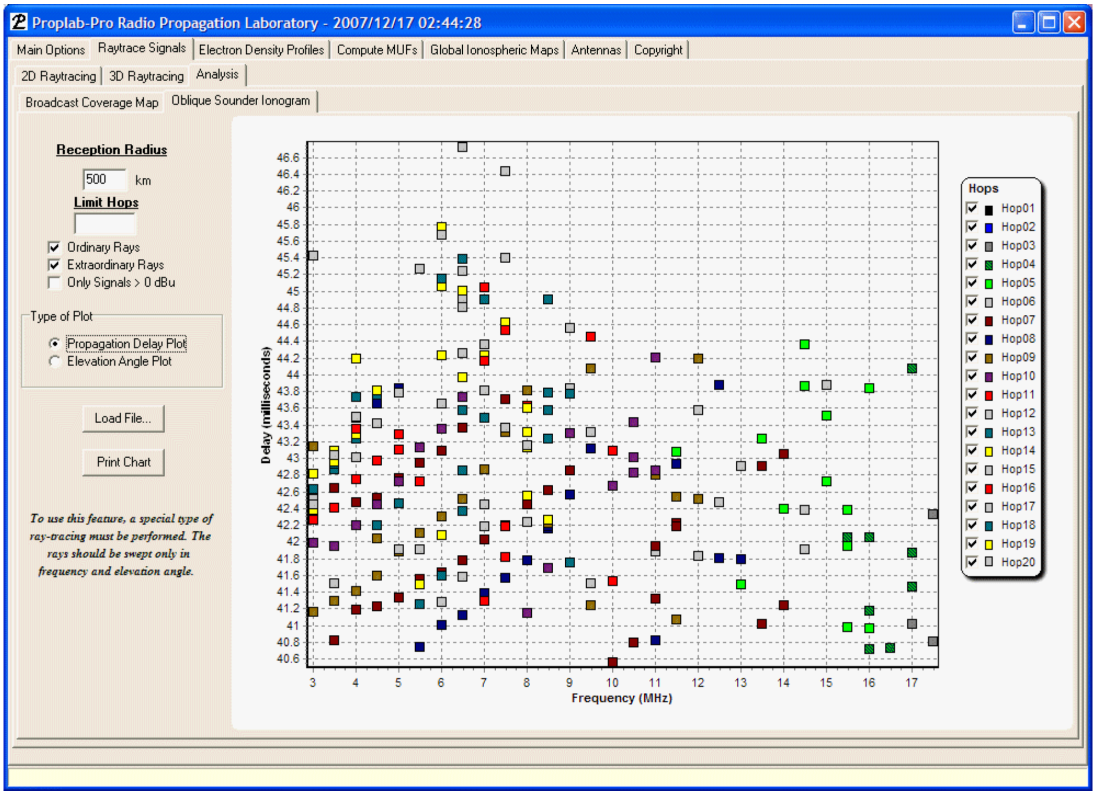
For a more in-depth discussion of this analysis technique, we once again refer you to the details in the manual for Proplab-Pro Version 2.

After we have performed this ray-tracing session, we can load the data and display it using this analysis feature. Here is a sample based on a quick and simple ray-tracing session.



These results were obtained over the Seattle to Sydney path discussed earlier in this manual, using a frequency that was varied from 3 MHz to 30 MHz at step intervals of 0.5 MHz and elevation angles that were swept from 0 to 40 degrees in 1 degree steps.

This plot shows the range of frequencies and elevation angles that can be received at the receiver.



This is a propagation delay plot of the same data. It shows how long it takes signals of varying frequencies and elevation angles to reach the receiver and is important because it helps identify multipathing effects and resultant signal distortion. For modem-based radio communications, this information can be used to help define the limits of communications speed on various paths.

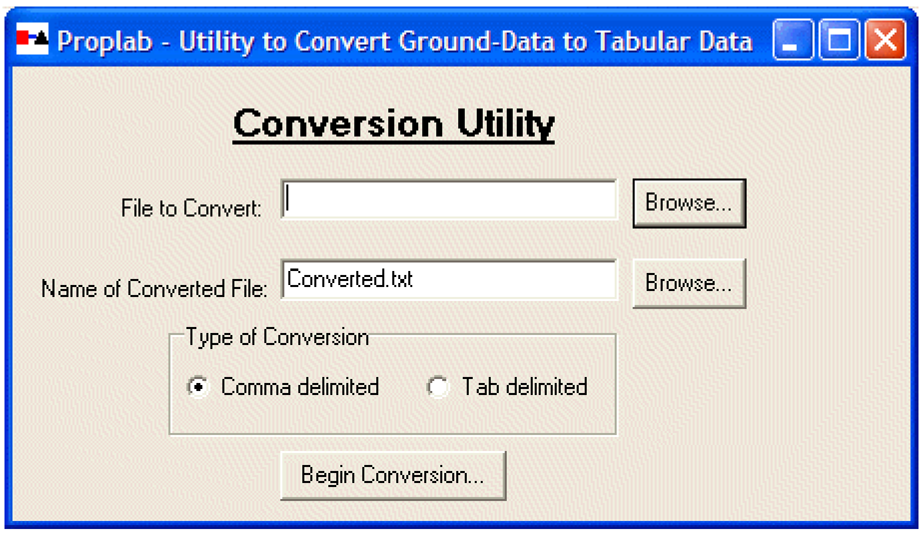
On both of these example charts, you can selectively enable or disable data related to specific hops by clicking on the checkboxes in the legend.

Utilities

Database extraction utility

Proplab-Pro comes equipped (post-Build 1002) with a new utility that allows the ground-based results to be exported to an external comma or tab delimited type format suitable for use in other software such as spreadsheets.

To initiate the conversions, run the "Convert" utility. The following screen will appear:



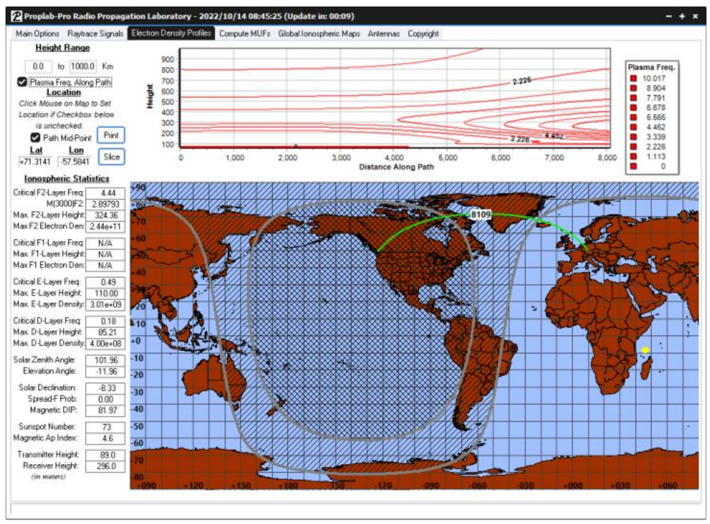
Click on the Browse… button next to the "File to Convert:" to select the ground database file you want to convert (files with extensions ".ryg"). Next, specify the filename you want the converted file to be saved as. The default is "Converted.txt". Finally, specify whether you want the new file to be saved in "Comma delimited" or "Tab delimited" format. Your spreadsheet software will dictate which format it is able to accept (most will accept either).

To begin the conversion, click on the "Begin Conversion…" button. The conversion process may take some time if the database file is large.

Slicing the Ionosphere

Beginning with version 3.2, build 40 (October 2022), Proplab-Pro has supported the creation of detailed slices of the electron density in the ionosphere.

A hint of this capability has always been available in the Electron Density Profiles tab, as shown below.



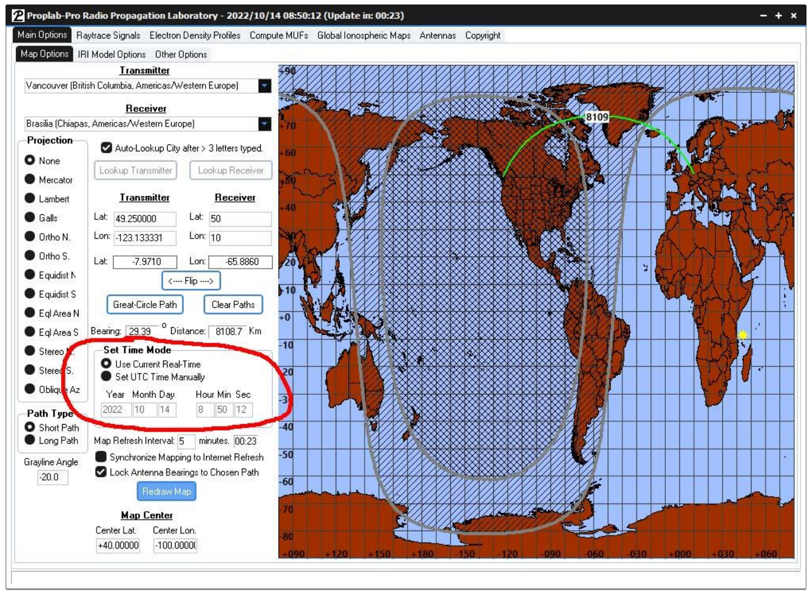
Imagine taking a knife and cutting a single line through the ionosphere along the great-circle path in green from Vancouver to Europe. At this particular date and time, and using the existing sunspot number and solar flux information that is defined in the Main Options / IRI Model Options tab, the electron density profile is plotted as plasma frequencies in the top contour map.

Unfortunately, it is difficult to see from the small graph precisely what is going on. And there is no control over the resolution of the collected data. In addition, there is no way to extract the electron density information or export it to another facility for investigation. This is often useful for researchers.

These features are now available in the software through the Slices button.

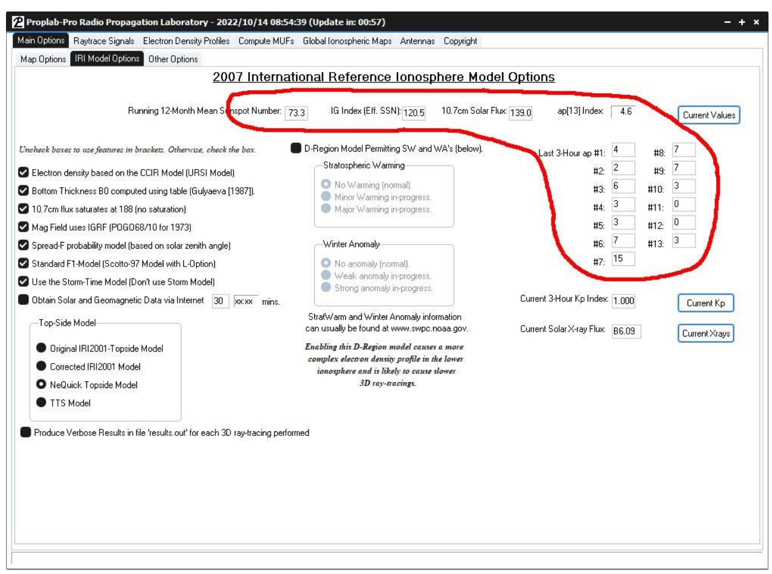
Before we explain these features, let's step through the process of creating an ionospheric slice. It is relatively simple to do.

The first step in generating an ionospheric slice is to set the correct time and date.



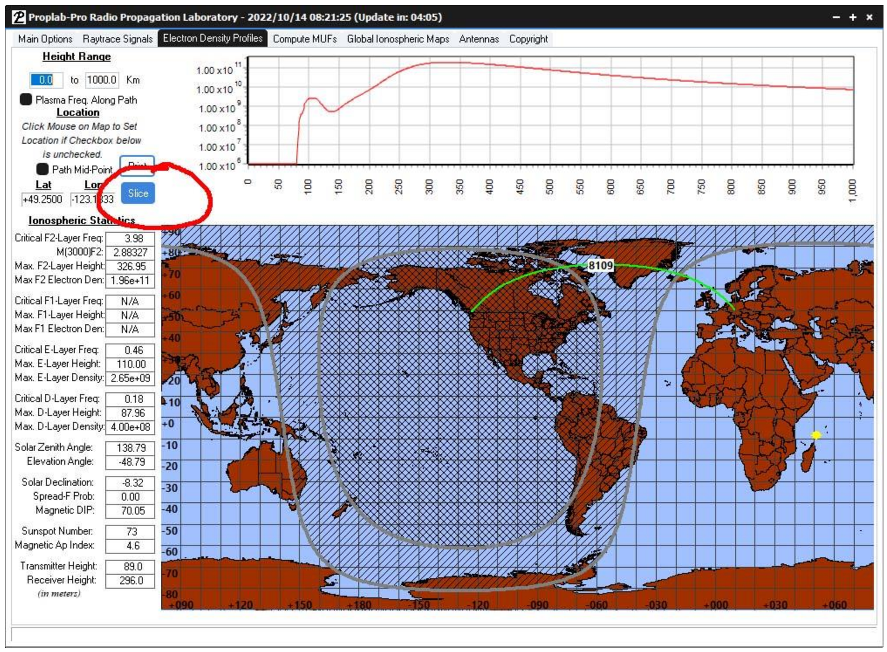
If you don't want to use the current real-time date and time, make sure you check the "Set UTC Time Manually" checkbox above and then set the current date and time for the ionospheric slice. In the discussion that follows, we will be using the current real-time of the computer.

Next, make sure that the current space weather parameters for the date you have specified are accurate by clicking on the IRI Model Options tab.

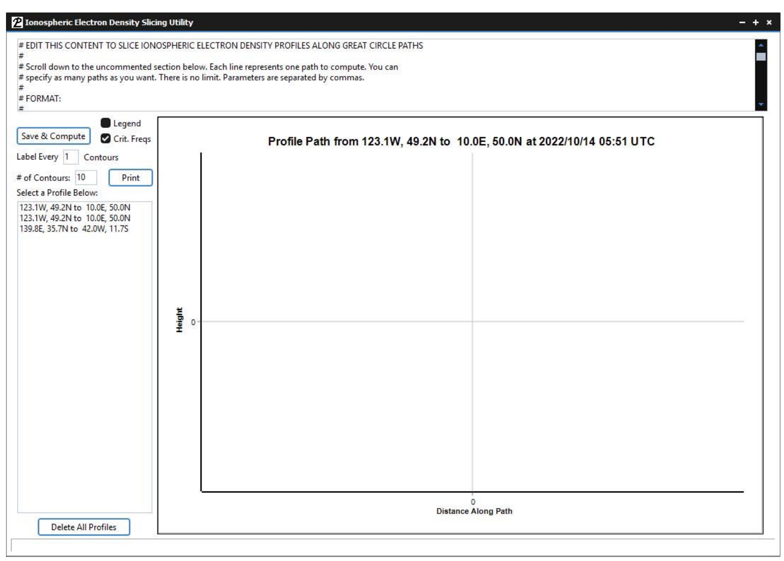


The top three numbers (running 12-month mean SSN, IG Index and solar flux) are the most important parameters, depending on the IRI model options you have chosen.

The transmitter and receiver locations are not necessary to specify on the Main Options tab. The ionospheric slicing utility does not use the configured transmitter and receiver location information. It obtains the geographic locations of the starting and ending points for the great-circles it computes from a text box that will be described shortly.



Next, go to the Electron Density Profiles tab and click on the Slice button. A new window will appear.

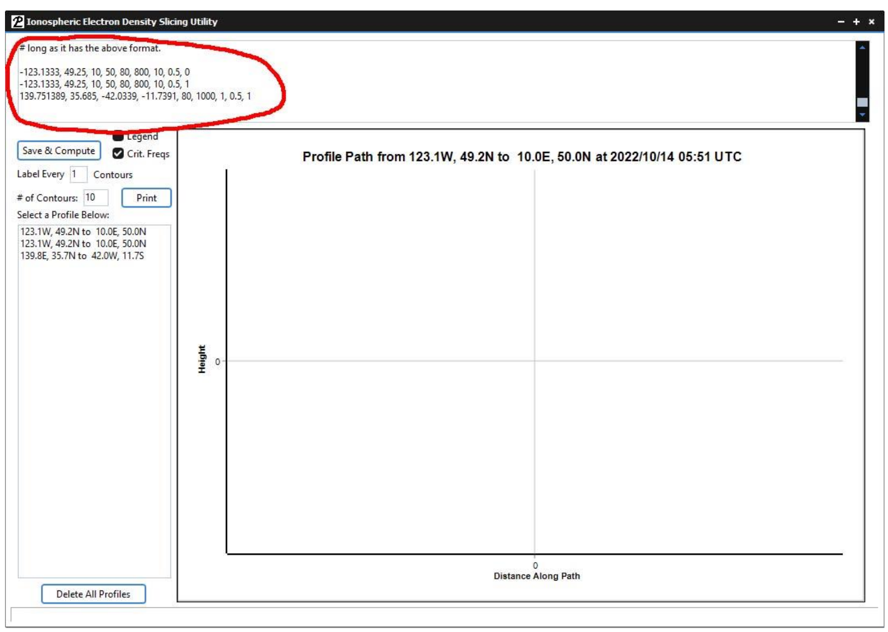


The top box of this window shows a file that is located in the Proplab operational folder and is named “Slices.txt”. This is an important file that Proplab uses to define how to slice the ionosphere, and how many slices to produce. We will describe it in a moment.

The panel on the left shows all of the ionospheric profiles that are defined in the top box, whether they have been computed or not. Each line in the left panel describes a file that is (or will be) stored in the operational folder of Proplab. Those files are named: “Slices-XXXXXX.txt”, where XXXXXX is an index number that starts at zero and is incremented by one for each profile that is created. Each of these files contains detailed electron density information in text format that is sliced from each path defined in the top box (or the Slices.txt file). These files can be imported into other software such as Excel, or read using user-defined routines outside of Proplab.

The panel on the right shows the actual computed electron density profiles. When you first click on the Slice button, this panel will be blank. But after you have computed the profiles defined in the top box, you can select the profiles in the left panel to display the electron density profiles for that path. This will all become clearer momentarily.

First, let’s get familiar with the top box (the Slices.txt) file and the proper format of the data used to generate the ionospheric slices.



Scroll down to the bottom of this window. This is an editable window. Read the commented lines (the lines that start with an ampersand sign #).

Each line of this box (each uncommented line of the Slices.txt file) represents one complete great-circle path to slice. Each line describes the geographical starting and ending points of that slice. It also describes the starting and ending altitudes (in kilometers) to use for slicing. It also describes the size of the steps along the great-circle path and in altitude to use in generating the slices. And finally, it defines whether the slice uses the short or long great-circle paths.

In the example above, there are three uncommented lines representing three separate and distinct great-circle paths to slice the ionospheric electron density. You can specify as many great-circle paths as you wish. There is no limit.

The format of each line is as follows. Note that although we state each parameter on a separate line below, all of the parameters must be given on a single line in the software.

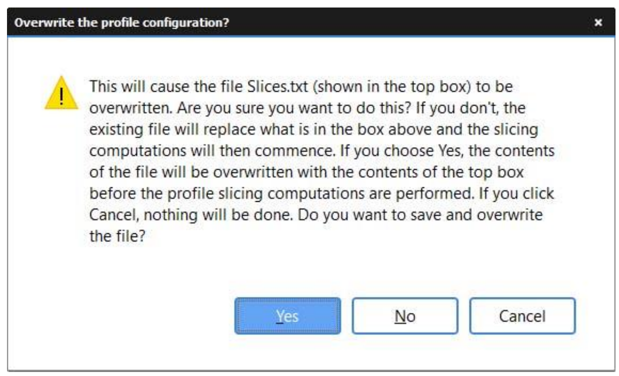
Format:

- Starting Longitude (negative values are west, as are values greater than 180 degrees).
- Starting Latitude (negative values are in the southern hemisphere).
- Ending Longitude
- Ending Latitude
- Starting altitude for the profile. The ionosphere doesn't usually have any serious electron density until you exceed about 80 km in altitude. You can specify any positive value here, but generally starting values around 80 km are sufficient.
- Ending altitude. The International Reference Ionosphere model used by Proplab does not compute ionospheric electron density profiles higher than 2000 km in altitude. Any value that exceeds 2000 here will be reset to 2000.
- Altitude step rate. This parameter defines the vertical resolution of the ionospheric electron density. For example, a value of 10 means that one data point will be computed every 10 km in altitude. You can use any positive decimal value here (i.e. 0.1 would be an altitude step of 0.1 km).
- Great-circle step rate. This value is given in degrees along the great-circle path. For example, a great-circle path that went all the way around the earth would encompass 360 degrees. A great-circle step rate of 1 degree means that the software would step along the great-circle path sampling the ionosphere at 1-degree distances from the starting location to the ending location. A value of 0.5 is used in the example above, which translates to a distance between points of about 56 km.

- Finally, the last parameter defines whether the software should slice the ionosphere using the short great-circle path or the long great-circle path. If the value here is a zero, the short path is used. If the value is a 1, the long path is used. It is possible to use the long-path to generate ionospheric slices that entirely encompass the Earth, if the geographic starting and ending locations are close to each other.

Once the parameters in the box above are set up correctly, with commas between the parameters and the proper date and time, etc., the slicing process can be commenced.

The slicing operation can be started by clicking on the Save & Compute button.



When this button is clicked, the above warning will appear. How you respond to it will determine whether the profiles you have set up in the top box are saved to disk (to the Slices.txt file) or whether the changes are ignored.

If you click Yes, any changes you made will be saved and the computations will then commence based on those changes.

If you click No, any changes you made will be discarded. In this case, the old Slices.txt file parameters are reloaded into the top box from your hard-disk. Computations are then commenced using the old parameters.

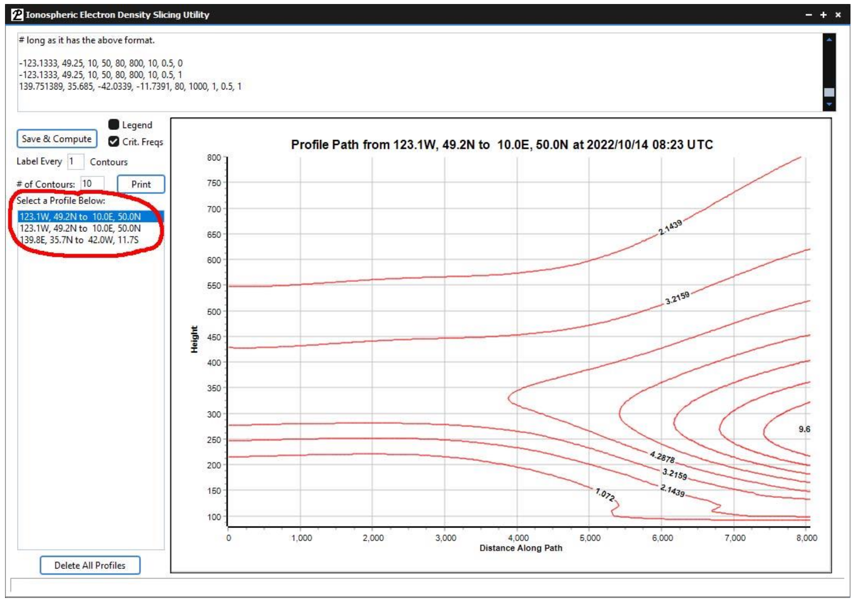
If you click Cancel, nothing is done and you are returned back to the main screen.

In most instances, you will click Yes. Any changes you made are then saved and the slicing operation is commenced.

After the slicing operation commences, you will see the progress of the operation in the status window at the bottom.

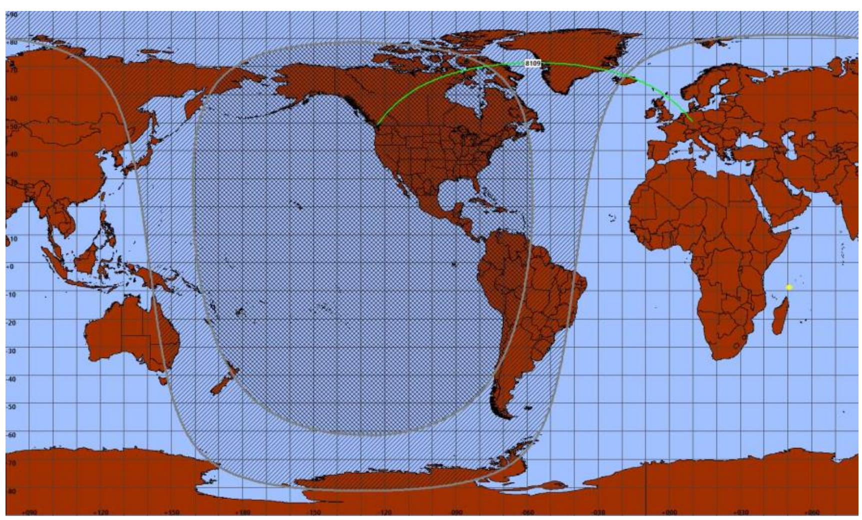
How long it takes the software to generate all of the slices will depend on your computer speed and the parameters you have specified in the top box. If you specify very small step rates or a large number of great-circle paths to compute, it could take a while to finish slicing everything. On most modern computers, provided you have used reasonable parameters, it should not take very long.

When the process is completed, you can click on one of the profiles as is shown below to display the results.



In this example, we clicked on the first profile. This great-circle path is a little over 8,000 km in length from Vancouver to Europe. Notice that the UTC date and time is set to real-time in the Main Options window of our example, so the current date and time is used for this slice.

Also notice that the “Crit. Freqs” checkbox is checked above, so the display does not show the electron density raw data. That data is internally converted into plasma critical frequencies before displaying them.

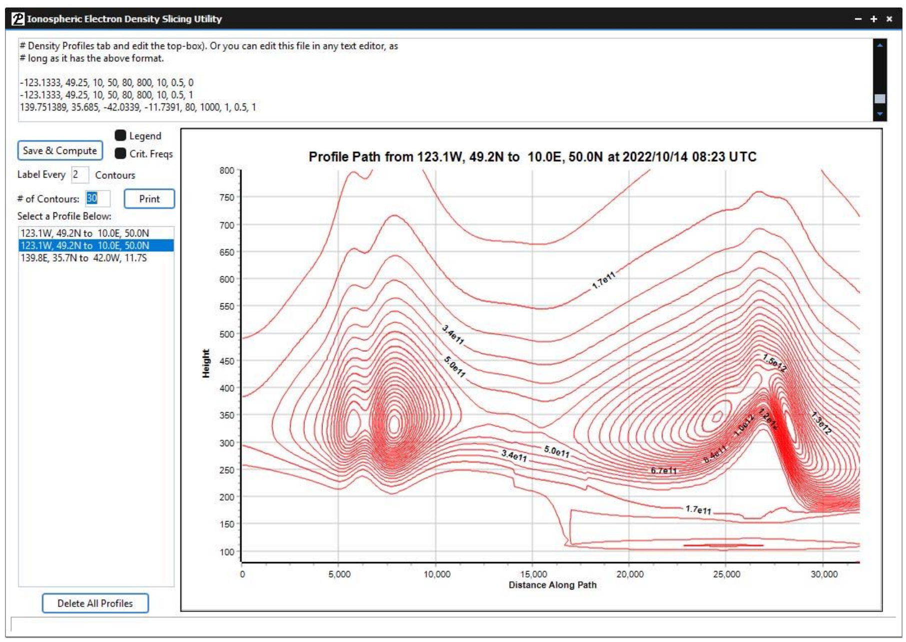


The great-circle path for this profile is shown above. Notice the location of the day/night terminator. The last leg of the profile enters daylight and we should expect both electron densities and critical frequencies to increase. This is indeed what we observe in the profile slice shown above.

Notice also that there is some tilt to the ionosphere, particularly from about the half-way point to the ending point. This asymmetry is due to the day/night terminator. In these regions, you could expect propagating radio waves to be refracted in non-standard ways (our 3D ray-tracing engine inside Proplab can handle these situations), resulting in non-great-circle propagation or even signal ducting between ionospheric layers.

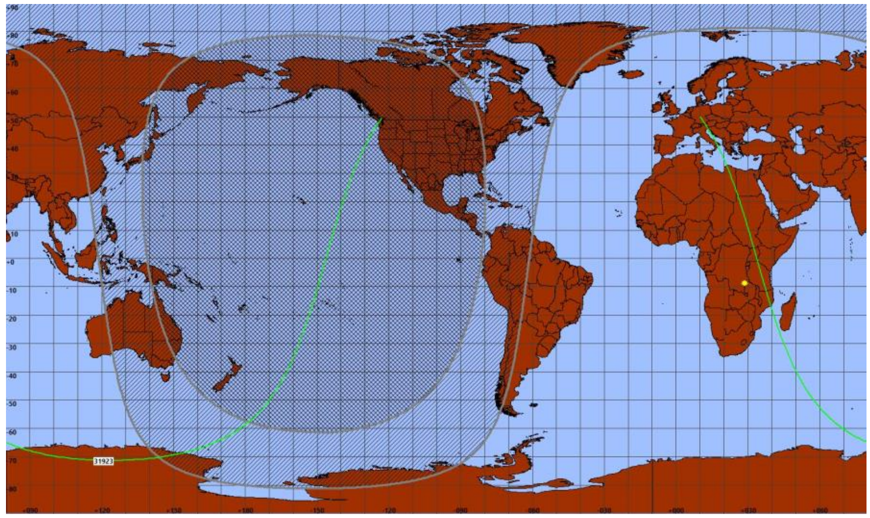
A great deal of information can be gleaned by studying these slices.

The second computed profile is much more complex.



Notice also that the distance is significantly greater as well (> 30,000 km) because we defined this path to be a long-path (see the last digit in the top-box, which is a 1).

The path of this profile therefore looks as follows.

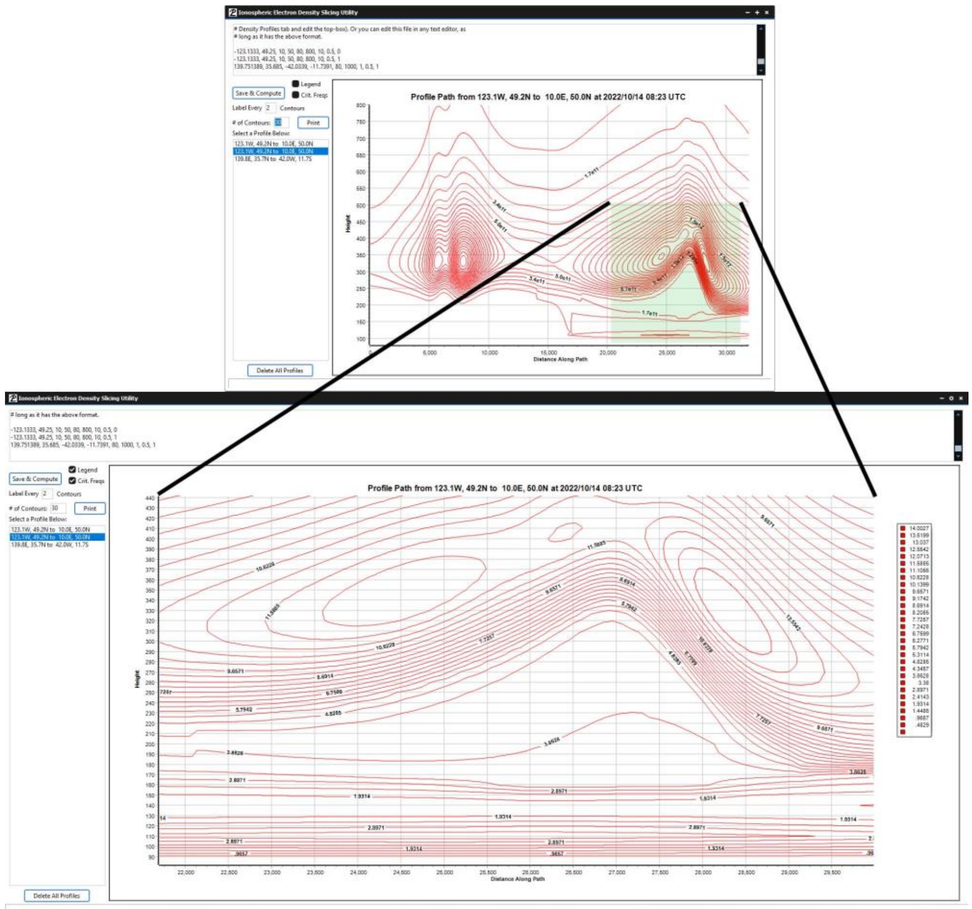


The complexity of the profile is due to the slice being made through the equatorial night zone, as well as through the equatorial day-zone where electron densities and critical frequencies peak.

To examine some of these features in greater detail, use your mouse, left-click inside the contour box and drag a box through the displayed profile from the upper-left to the lower-right. We have done this below to examine one of the equatorial regions in greater detail.

Note in the example below that we have increased the number of contours that are drawn from the standard value of 10 to 30. This increases the visible resolution of some features and may be useful to play around with.

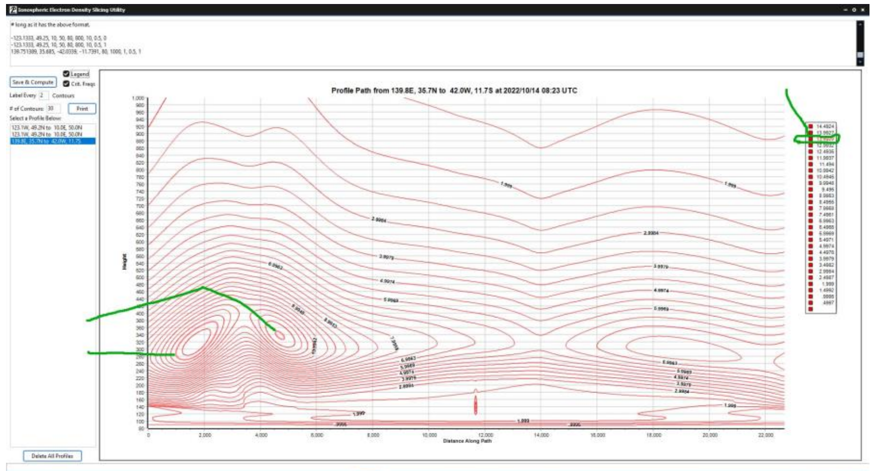
You can also change how often the labels are shown on-screen. If you want every line labelled, change the "# of Contours" to 1. If you want every other line labelled, change the value to 2. And if you don't want any labels to be shown at all, set this value to zero.



In the above example, the area of the green box is where we left-clicked and dragged our mouse to zoom in, revealing the significant tilting that can occur through the equatorial region during the day.

While you are zoomed in, you can pan around by RIGHT-clicking and dragging the mouse.

To zoom back out, left-click the mouse again, but this time drag the mouse from the bottom-right toward the upper-left (making a rectangle in the opposite direction). The display will then zoom back out.



By including a legend in the plot, as shown above for the third profile example, you can hover your mouse over the legend to quickly identify the corresponding contours that apply to that legend value. In the above example, the mouse is hovered over the third legend value from the top. When we do that, the corresponding contours are made bold in color.

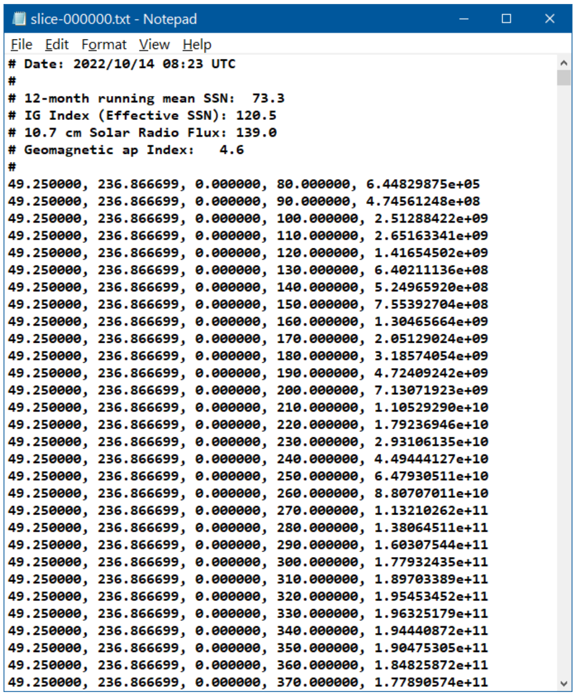
Anytime you wish to print the contour plots, you can click on the Print button. The contour plot will then be sent to your default printer.

After you have computed ionospheric slices, you can access the text file outputs by navigating to the operating folder where Proplab-Pro resides. This is usually C:\Program Files (x86)\Proplab3

In that folder, you should find the sliced ionospheric files named “Slices-000000.txt”, “Slices-000001.txt” and “Slices-000002.txt”, representing the three profiles we sliced in the foregoing discussion for those who are following along.

These files contain the detailed electron density information that can be imported into other tools, as required.

Their format looks like this.


slice-000000.txt - Notepad

File Edit Format View Help

```
# Date: 2022/10/14 08:23 UTC
#
# 12-month running mean SSN:  73.3
# IG Index (Effective SSN): 120.5
# 10.7 cm Solar Radio Flux: 139.0
# Geomagnetic ap Index:   4.6
#
49.250000, 236.866699, 0.000000, 80.000000, 6.44829875e+05
49.250000, 236.866699, 0.000000, 90.000000, 4.74561248e+08
49.250000, 236.866699, 0.000000, 100.000000, 2.51288422e+09
49.250000, 236.866699, 0.000000, 110.000000, 2.65163341e+09
49.250000, 236.866699, 0.000000, 120.000000, 1.41654502e+09
49.250000, 236.866699, 0.000000, 130.000000, 6.40211136e+08
49.250000, 236.866699, 0.000000, 140.000000, 5.24965920e+08
49.250000, 236.866699, 0.000000, 150.000000, 7.55392704e+08
49.250000, 236.866699, 0.000000, 160.000000, 1.30465664e+09
49.250000, 236.866699, 0.000000, 170.000000, 2.05129024e+09
49.250000, 236.866699, 0.000000, 180.000000, 3.18574054e+09
49.250000, 236.866699, 0.000000, 190.000000, 4.72409242e+09
49.250000, 236.866699, 0.000000, 200.000000, 7.13071923e+09
49.250000, 236.866699, 0.000000, 210.000000, 1.10529290e+10
49.250000, 236.866699, 0.000000, 220.000000, 1.79236946e+10
49.250000, 236.866699, 0.000000, 230.000000, 2.93106135e+10
49.250000, 236.866699, 0.000000, 240.000000, 4.49444127e+10
49.250000, 236.866699, 0.000000, 250.000000, 6.47930511e+10
49.250000, 236.866699, 0.000000, 260.000000, 8.80707011e+10
49.250000, 236.866699, 0.000000, 270.000000, 1.13210262e+11
49.250000, 236.866699, 0.000000, 280.000000, 1.38064511e+11
49.250000, 236.866699, 0.000000, 290.000000, 1.60307544e+11
49.250000, 236.866699, 0.000000, 300.000000, 1.77932435e+11
49.250000, 236.866699, 0.000000, 310.000000, 1.89703389e+11
49.250000, 236.866699, 0.000000, 320.000000, 1.95453452e+11
49.250000, 236.866699, 0.000000, 330.000000, 1.96325179e+11
49.250000, 236.866699, 0.000000, 340.000000, 1.94440872e+11
49.250000, 236.866699, 0.000000, 350.000000, 1.90475305e+11
49.250000, 236.866699, 0.000000, 360.000000, 1.84825872e+11
49.250000, 236.866699, 0.000000, 370.000000, 1.77890574e+11
```

The commented section shows the parameters that were used to generate this profile.

The format of this file is simple:

Latitude, Longitude, Distance, Altitude, Electron Density

The geographical point coordinates of each data point, the distance of that point along the great-circle path, as well as the altitude of each point is given together with the computed electron density.

If you want to archive specific sliced results, don't only save the Slices-XXXXXX.txt files. Also remember to archive the associated "Slices.txt" file that defines each of the paths. This is important if you ever want to recall and redisplay profiles using Proplab-Pro.

The file Slices.txt defines all of the paths and each uncommented line of that file corresponds to one of the Slices-XXXXXX.txt files. For example, the first uncommented line of the Slices.txt file corresponds to the Slices-000000.txt file. Second uncommented line of the Slices.txt file corresponds to the Slices-000001.txt file, and so on. Proplab needs all of these files if you want to redisplay computed results.

If you ever want to delete all of your sliced profiles from your hard-disk (all of the Slices-XXXXXX.txt files), you can do so by clicking on the “Delete All Profiles” button. This will not delete the main Slices.txt file that is displayed in the top of the window in Proplab, but it will delete all of the Slices-XXXXXX.txt data files. After this is done, you will need to click on the Save & Compute button to recompute the profiles.

Conclusion

Proplab-Pro Version 3 is a significant tool for radio engineers.

We will occasionally make available maintenance releases to correct bug reports and add functionality.

Thank you for your support.