AircraftScatterSharp – An Aircraft Scatter Assistance program for Datahounds

--by Roger Rehr, W3SZ

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I wrote AircraftScatterSharp to assist those wanting to do aircraft scatter. This text highlights improvements that I have made to the software both recently and over the past several years. AircraftScatterSharp has several important capabilities:

1. Real-time capture and display of plane position data derived from internet plane servers, from a local RTL1090 server, or both
2. Display of the direct path line between two stations, along with skew lines to allow a quick assessment of the angular deviation of an aircraft's position from the direct path between the stations, and a midpoint circle to show when an aircraft is within a specified distance from the midpoint of the path. Path altitude and elevation/obstruction profiles are also shown.
3. Highlighting of aircraft near the ideal position for scatter, based both on distance from the path midpoint and angular deviation from the path.
4 Real-time calculation of path loss, received signal strength, and signal margin at both stations based on plane location and user-adjustable station parameters, using either bistatic aircraft scatter, Yeh troposcatter [1] or free path formulas. Radar Cross Section may either be selected from a list or set automatically based on the aircraft's airframe type, which is determined from the ADS-B ICAO code value.
5. Real-time estimation of Doppler shift and its rate of change
6. An integrated SQLite database that allows you [1] to save information on all planes appearing on your screen for however long you want [minutes, hours, days, weeks, months] and [2] to then analyze that data to determine when aircraft scatter opportunities will most likely occur. You can analyze the data without interrupting its collection, and powerful SQL search functions are automatically included and easily selectable using only mouse-clicks to generate the SQL query statements.
7. An Experimenters' Mode where you can manually set various parameters and use the mouse to vary "plane" position and see the effects of those settings on RF signal parameters, troposcatter angle, aircraft scatter angle, etc.
8. Two SRTM-related capabilities: It will find the ten highest peaks within a user-specified map-defined rectangle and it will use the Longley-Rice ITM model[2] [3] to display RF attenuation for any frequency between 50 Mz and 24 GHz at distances of up to 500 km for either 0-360 degrees or for any desired azimuthal wedge.

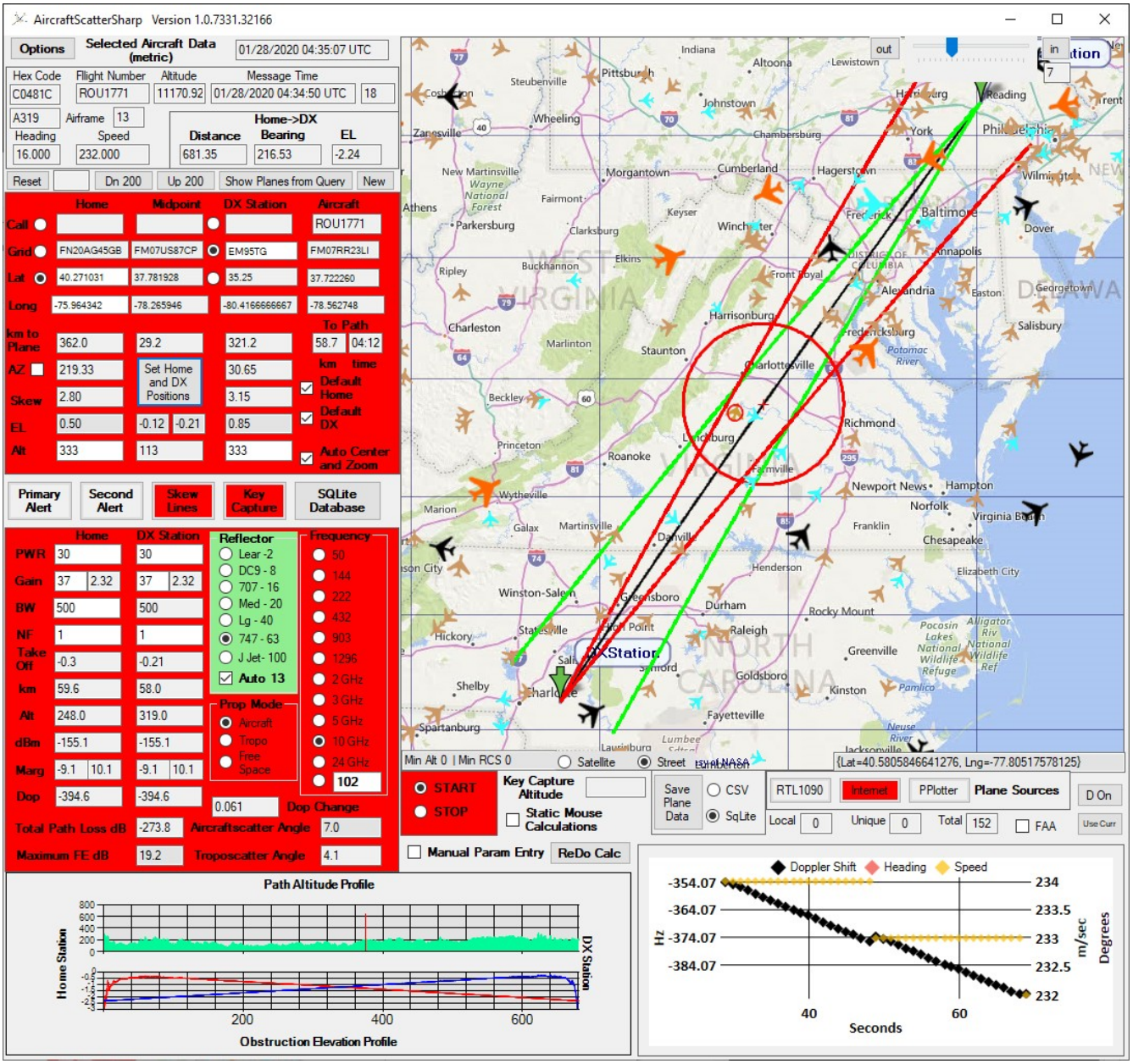
The SQLite database provides something that has been missing from previous aircraft-scatter software (except for my earlier program mentioned above, which also included this feature). For EME we have software predictors of when the moon will be "available" to us as a reflector and for rain-scatter we have

RainScatter, by Andy Flowers, K0SM [4] to give us this information. But there has been nothing similar for aircraft scatter until AircraftScatterSharp came along.

Below I will describe the program in some detail. For detailed "Getting Started" instructions on installing and using it, go to the appendix.

Getting Started In order to start an aircraft-scatter session, one needs to enter the Home and DX station position information. This can be done in several ways which will be detailed below. After this has been done the user then left-clicks the "Set Home and DX Positions" button. That sets the Home and DX station locations and sets up the path. If one wants to see the midpoint circle and the skew lines, one then clicks the "Skew Lines" button to place the direct path line and the midpoint circle and skew lines onto the map. One then selects either the local or the internet plane server or both, and clicks "Start" to start the real-time aircraft display. Before doing all of this for the first time, there are some options that should be set as described in the appendix to this document. More details about all of this will be explained more fully in the text below.

Main Form AircraftScatterSharp's main form is shown below.



On the right side of the display is a map which contains a real-time display of all aircraft positions downloaded from the server[s] that meet certain criteria set by the user. The aircraft icons shown on the map represent real-time aircraft positions and headings. The size of each aircraft's icon is indexed to its Radar Cross Section (RCS) using the formula Size = 15 + RCS/3. Icon color also gives an indication of size, with planes with RCS = 1 – 9.99 being colored light blue, those with RCS = 10 – 29.99 being colored beige, those with RCS = 30-49.99 being colored black, and those with RCS greater than or equal to 50 being colored red. Planes from a local ADS-B server will be colored bright green. If you hover over a plane's icon the icon size will change to 35 and the icon will turn a yellow-green color and a black ring will be placed around the icon. If a plane is selected for in-depth analysis by left-clicking on it, then a black ring will be placed around it, except for "black" planes which will have a red ring placed around their icons.

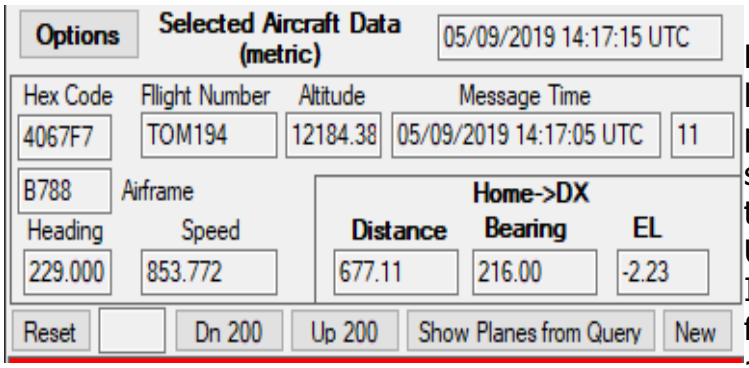
If manual mode is selected, a hot-pink aircraft icon will be placed at the manually-selected point on the map.

Below the map on the left is a path altitude profile and a path elevation profile for the path between the home and DX stations. The path altitude profile will only appear if SRTM3 data files have been installed [5] [6]. To the right of these profile displays is the Doppler display.

To the left of the map is the data display area. This section of the display shows data for an aircraft that has been selected by left-clicking its marker on the map display. Selecting an aircraft in this fashion puts a black ring around the plane icon for easier identification, as noted above. In the image above you can see the selected plane slightly below the center of the map. It is located near the inter-station line well inside the red "Secondary Alert" circle, between Lynchburg and Charlottesville. The plane is colored beige because its RCS is 13.

The path between W3SZ and W4DEX (the Home and DX stations) shown on the map above was selected by clicking the "Grid" radio buttons for each station and then entering their 6-10 digit grids in the adjacent text boxes, and finally clicking the "Set Home and DX Positions" button. The program then calculated and displayed the latitude and longitude values for each station and set the path. If, instead, the "Lat" radio button for each station was clicked and the appropriate latitude and longitude values were entered into the corresponding text boxes, and finally the "Set Home and DX Positions" button clicked, the program would calculate and display the 10-digit grid locator for each station in the appropriate text boxes and then set the station locations and the path.

The Aircraft Scatter Sharp program package also contains a call3.txt file, and AircraftScatterSharp can use this call3.txt file to supply location information for stations included in the file. New stations can be added to the call3.txt file by AircraftScatterSharp or by manually editing the call3.txt file. As long as a given callsign is contained in the call3.txt file and that file is placed in the appropriate directory, you can also enter location information for either the Home or DX station by typing that station's call into the appropriate "Call" text box when the "Call" radio button has been clicked for that station and then clicking the "Set Home and DX Positions" button.

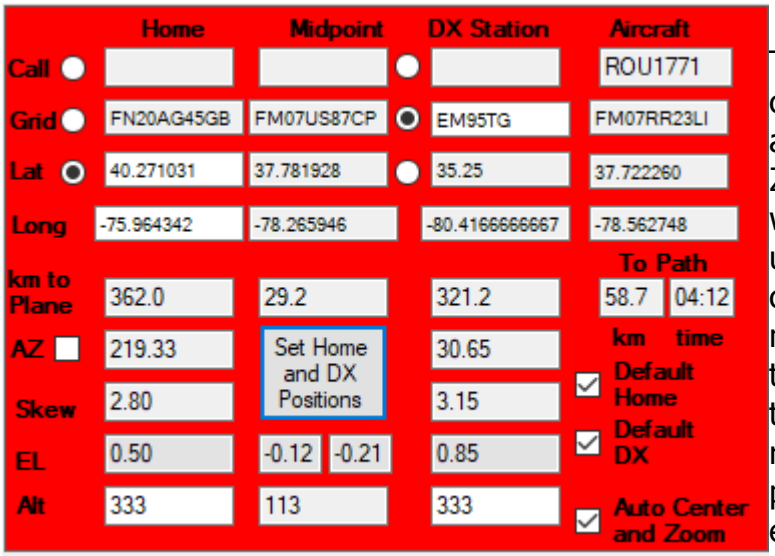


Basic Plane Data Area On the left is an image of the topmost portion of the data area on the left side of the main form. At the very top it shows the current time in UTC. Just below that, it shows the ICAO hexcode for the plane, its flight number, altitude, and the time at which its data was received. Just

below that on the left is the selected plane's airframe type. Below that are aircraft heading and speed, and on the right is a description of the length and bearing of the path from the home station to the DX station, along with a notation of the elevation of each station relative to the horizon as seen from the other station.

As you can see above,the next portion of the form, just below this section, has five buttons, labeled "Reset", "Dn 200", "Up 200", "Show Planes from Query", and "New" and a text box. These are used to control the display of planes from the stored SQLite database, and they will be discussed more fully below.

Station and Aircraft Position Data Area The portion of the form just below the above sections of the form is colored red in this instance, and is shown below.



This section is colored red in this case because there is at least one aircraft within the Secondary Alert Zone. This alert zone is activated when a plane is within the red user-defined "optimal range circle" that is drawn around the midpoint of the path (the radius of this circle is user-adjustable via the "Options" "Alerts" page). The red color of this section of the program display provides an easily visible indication that the secondary alert has been activated. Although the likelihood of a successful aircraft scatter contact is less for planes in this zone than it is for those in the Primary Alert Zone (which will be described in the section titled "Path Loss and Signal Margin Display" below), the likelihood of success for planes in the Secondary Alert zone is higher than it is for planes that are not in either the Primary or Secondary Alert zones.

This section of the form contains 4 columns of text boxes. These respectively, from left to right, give positional information about [1] the Home Station, [2] the midpoint of the path between the Home and DX stations, [3] the DX Station, and [4] the selected aircraft. Checking the check box to the right of "AZ" activates the N1MM Rotor Controller interface. Then the antenna tracks the selected plane.

This information includes for the Home and DX stations callsign (optional), grid square, latitude, longitude, km to plane, azimuth to plane, elevation of the selected aircraft as seen from that station, skew angle of the selected aircraft's position relative to the direct path as seen from that station, and altitude of the station location's antenna above sea level in meters (which can either be entered by user or populated from the SRTM3 data if is available and should be the sum

of the terrain's elevation above sea level plus the tower and mast height). If the selected aircraft's elevation as seen by the Home station is below the take-off angle of the Home station, then the Elevation box for that station will be colored red instead of gray. Behavior for the DX station is similar in this regard.

Callsign, grid square, latitude, longitude, and altitude are user-adjustable by entering these values into the text boxes. As was noted above, radio buttons allow the user to select whether station location is specified by callsign look-up, grid square, or latitude and longitude. If Key Capture is turned on, one can also use the latitude and longitude of a point on the map to position the Home station location at that point by selecting manual lat/long entry by clicking the "Lat" radio button and then positioning the mouse cursor over the desired location on the map and then hitting <Ctl>F1. One can similarly position the DX station by positioning the mouse cursor over the desired location on the map and then hitting <Ctl>F2 after the "Lat" radio button has been selected. When <Ctl>F1 or <Ctl>F2 is used in this manner to automatically locate either the Home or DX station location, the program will also calculate the elevation of that location if SRTM3 data has been downloaded by the user and placed in the appropriate file location, using that SRTM3 data. To this value the user must manually add his and the DX station mast heights unless he has entered those values on the Options>>Home Location page. If these values have been entered on the appropriate Options page, then they will be automatically added to the elevation values obtained by using <Ctl>F1 and/or <Ctl>F2. Note that if either the "Grid" or "Call" radiobutton has been selected for either the Home or DX station, then this method of setting the location for that station is disabled, by design.

The "Aircraft" column at the extreme right side of this portion of the display contains two small text boxes under the label "To Path". The small box on the left is labeled "km" and gives the distance from the selected aircraft to the inter-station path <u>along the heading that the aircraft is currently following</u>. The small box on the right is labeled "time" and gives the time in minutes and seconds that it will take the plane to reach the inter-station path, flying along its current heading at its current speed. These values, as well as the other "aircraft-related" values in this section of the display are updated once each second.

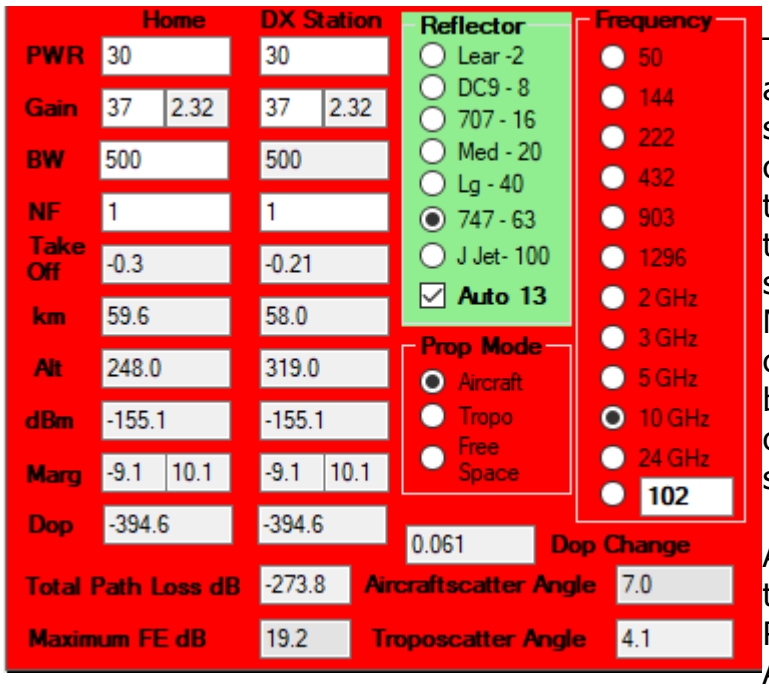
This section of the display also contains 3 check boxes in its lower right corner. Checking the box labeled "Default Home" will cause the program to use for the Home Station location the latitude and longitude entered on the "Home Location" Options page, if the "Lat" radio button for the Home Station is also selected. The "Default DX" check box provides an identical function for the DX Station. The box labeled "Auto Center and Zoom" will cause the map display to recenter and resize any time a new location is chosen for either the Home or the DX Station, centering the display on the midpoint of the inter-station path. I check this box when first setting up a path, but then leave it unchecked thereafter.

Alert, Skew, Key Capture and SQLite Database Buttons Moving further down the data portion of the form the next portion of the display, shown immediately above, contains buttons that [1] activate or deactivate the audio primary and [2] secondary alarms but do not affect the panel color changes that accompany these audio alerts, [3] display or hide the skew lines and midpoint circle display, [4] activate or deactivate key capture, and [5] bring up the SQLite database query and analysis page. As noted above, the secondary alert, if activated, sounds when any plane enters the midpoint circle. The primary alert, if activated, sounds if at least one of those planes is also within both sets of skew lines. There are multiple functions that can be activated by Control Key combinations when the "Key Capture" button is activated. These will be listed if one hovers over the Key Capture button and are also listed on the Options page labeled "Key Capture", and can also be displayed by typing <Ctl>F9 if Key Capture has been activated. These functions include:

<Ctl>F1 will place the latitude and longitude of the point under the mouse cursor in the Home Station position boxes, **if** the manual entry "Lat" radio button is selected for the Home Station.
<Ctl>F2 will place latitude and longitude of the point under the mouse cursor in the DX Station position boxes, **if** the manual entry "Lat" radio button is selected for the DX Station.
<Ctl>F3 will place the altitude of the point under the mouse cursor into the Key Capture Altitude text box beneath the map.
<Ctl>F4 Displays a message box showing Latitude, Longitude, Altitude, and Grid for the point chosen when the F3 key was last used as described above.
<Shift>F4 is equivalent to **<Ctl>F3** followed immediately by **<Ctl>F4**.
<Ctl>F5 Activates ToolTips for all forms.
<Ctl>F6 Deactivates ToolTips for all forms.
<Ctl>F7 Brings up a web page showing information for the selected plane's ICAO 6-digit hexadecimal identifier. For this you need to register at airFrames.org. This will be described below.
<Ctl>F8 Brings up a Flight Aware web page showing both current and historical information for the selected plane's Flight Number.
<Ctl>F9 Shows a list of all Key Capture functions.
<Alt>A Allows user to set a lower altitude limit for planes displayed.
<Alt>R Allows user to set a lower RCS limit for planed displayed.
<Alt>E Allows user to set a lower elevation limit for aircraft elevation as seen from either end of the inter-station path.
<Alt>M Turns on or off the display in the "Key Capture Altitude" box of the elevation of the map point under the mouse cursor. This is useful for determining the best location to site an antenna, and also in looking for local path obstructions.

<Alt>P Displays a second form for finding peaks and creating Longley-Rice ITM method-based attenation plots.
<Alt>C Erases the coverage plots and markers placed by the Longley-Rice-related methods.
<Alt>Q Terminates a peak-finding or Longley-Rice-based calculation.
<Ctl>Home Used on the SQLite database page to center a database query around a geographic point on the map.
<Ctl>Insert and **<Ctl>Delete** Used on the SQLite database page to set two ends of a Great Circle path along which a database query will return planes.
<Ctl>Up-Down-Right-Left Arrows Used on the SQLite database page to set North/South/East/West boundaries for a rectangular query box. Also used by the peak-finding routine accessed by <Alt>P to define an area of interest.

Path Loss and Signal Margin Display Area Located immediately below these buttons, the next section of the display is shown below and is used for entry and display of RF-related information: expected path loss and resultant signal strengths and signal margins at both the Home and the DX stations and Doppler shift and its rate of change. This section will be colored red if a plane is both within the midpoint circle and also within the skew lines (i.e., if the primary alert is activated). This section will have a gray background if no planes are within the primary alert zone.



To perform the RF calculations for a selected aircraft, the user first selects the desired aircraft by left-clicking on it, and then selects in the section labeled "Reflector" (see the image on the left) the plane size category (Lear, DC-9, 707, Med, Lg, 747,or J Jet) by left-clicking the appropriate radio button. These select RCS values of 2, 8, 16, 20, 40, 63, and 100 sq. m respectively.

Alternatively, the user may click the "Auto" checkbox in the Reflector section, and AircraftScatterSharp will then automatically select the RCS based on the 4-digit ICAO airframe type designator displayed in the text box described above and labeled "Airframe". Not all airframe types are in the database, and if the selected aircraft is not in the database then the RCS value selected by the radio buttons above this checkbox will be used to determine the RCS value used in the calculations. In the case illustrated here the airframe <u>is</u> in the database and so the "Reflector" box has a light green background, the estimated RCS of 41 m^2 is displayed as shown, and the value of

41 is used for the RCS in the program calculations.

The user then selects the desired frequency band by clicking on the appropriate radio button in the box labeled “Frequency”. Next the user enters into the appropriate text boxes the power (“PWR” in watts), antenna gain (“Gain” in dBi), receiver bandwidth (“BW” in Hz), and receiver noise figure (“NF” in dB) for both the Home and DX stations (except that the receiver bandwidth is entered only for the Home Station and identical bandwidth for the DX station is assumed). Once this has been done, the program continuously calculates and displays the expected received signal level, signal margin, and total path loss for both Home and DX stations in real time, as well as Doppler shift and its rate of change if there is adequate data available for the selected aircraft. The station information is remembered between sessions, so it only needs to be entered once unless it changes.

Under these text boxes are text boxes which display for both Home and DX stations [1] the Take Off angle in the text boxes labeled “Take Off”, [2] the distance in km to the first path obstruction in the text boxes labeled “km”, and [3] the altitude (in meters) of that obstruction in the text boxes labeled “Alt”. These values are derived from the station location and the SRTM3 datasets.

Below those text boxes are the expected received signal level at each station in the text boxes labeled “dBm”, and just below that there are two text boxes for each station on the line labeled “Marg”. The first box for each station on this line shows the value of the receive signal margin without considering the effects of Forward Scattering Enhancement. The second box shows the signal margin that will occur if maximum FSE for the extant plane/station geometry is obtained. This value thus equals the value shown in the first “Marg” box for that station plus the value in the “Maximum FE” text box shown at the very bottom of this section of the display.

Beneath the signal margin text boxes are the text boxes that report the Doppler shift of the signal scattered from the selected aircraft as well as its rate of change. The Doppler shift is reported in Hz and its rate of change is reported as Hz/second. These text boxes are complemented by the Doppler graphic display which is below the map on the right side of the display and which will be discussed more below.

At the bottom of this section of the display, below the Doppler text boxes, are text boxes for the “Total Path Loss dB” excluding FSE effects, the “Aircraftscatter Angle” in degrees, the “Maximum FE dB” and the “Troposcatter Angle” in degrees.

The “Total Path Loss dB’ box and the “Marg” and “dBm” boxes will display the values for either aircraft scatter, troposcatter, or free space propagation, depending upon which radio button in the “Prop Mode” group box is selected. In this way one can easily compare signal levels and signal margins for aircraft

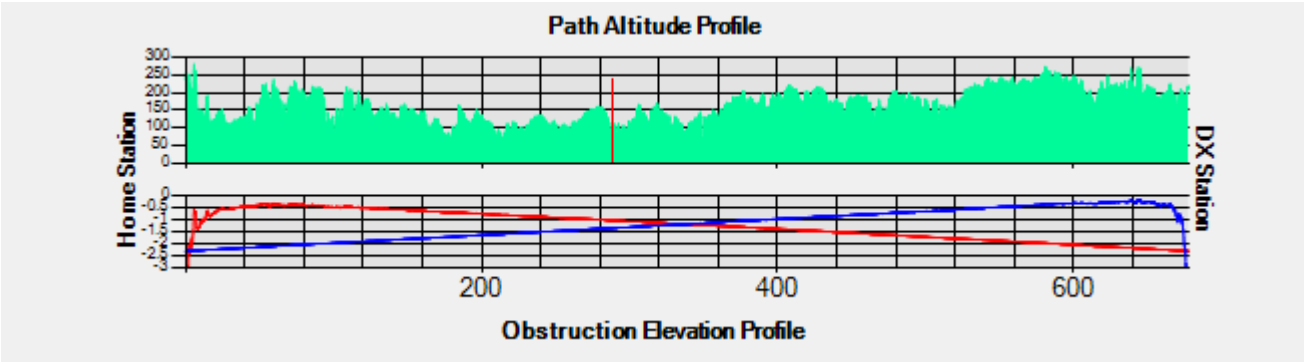
scatter vs troposcatter for any situation, and compare both to what the free-space loss would be for a similar station path if a line of sight were present between the two stations.

"Static Mouse Calculations" Check Box The check box located beneath the map and just to the right of the "Start" and "Stop" buttons and labeled "Static Mouse Calculations" is provided so that the calculations just described can be made for a theoretical aircraft that is positioned statically at a user-selected point on the map. If one <Ctrl>-left-clicks (left-clicks while holding down the <Ctrl> key) on any map point, then a hot-pink aircraft icon will be placed at that point and all calculations will be performed for a theoretical aircraft located at that point rather than using an aircraft position downloaded from one of the plane servers as the scattering object (see the first illustration in this article or the illustration on the next page to see this control).

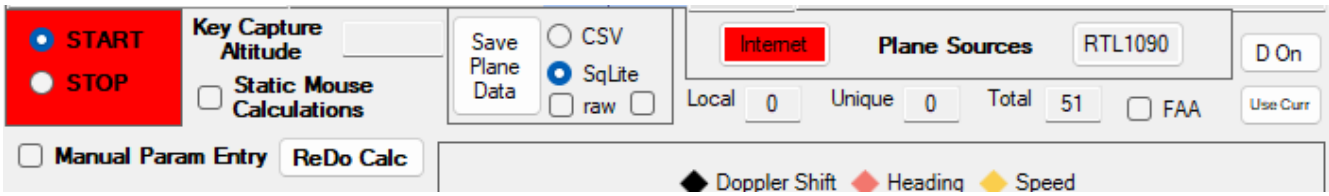
However, unless this "Static Mouse Calculations" box is checked, then the plane location and parameters derived from this location will be updated each second using the values for speed, heading, and altitude given in the text boxes in the "Basic Plane Data Area" described above. Activating this check box allows path analysis to be performed for any given map position even in the absence of any aircraft at the desired position.

<Ctrl>-left-clicking in this manner "opens" the Altitude, Heading, and Speed text boxes in the "Basic Plane Data Area" so that the user can enter specific values into these boxes in order to evaluate the effect of changes in these parameters. If one enters these parameters in this fashion with the "Static Mouse Calculations" box checked, and then unchecks it, a dynamic evaluation will be done beginning at the selected location and then for those points updated each second based on the altitude, heading,and speed data entered by the user in these boxes. If one subsequently selects a "real" aircraft from the map display, then these text boxes are again "closed" to user entry.

Path Altitude Profile and Obstruction Elevation Profile Immediately below this section of the form are the the "Path Altitude Profile" and the "Obstruction Elevation Profile" graphs, both of which will be displayed only if the SRTM3 files have been downloaded and properly installed. If an aircraft has been selected, it will appear as a vertical red line superimposed on the Path Altitude Profile. Such a red line is near the midpoint of the Path Altitude Profile shown below.



Start and Stop Buttons To the right of the RF calculations section of the display, beneath the map, are the "Start" and "Stop buttons that start or stop the real-time display of aircraft on the map, as shown in the image immediately below. It is necessary to click on "Start" to initiate downloading of plane information.



Just to the right of the "Start" and "Stop" buttons is the "Static Mouse Calculations" check box that we discussed above.

Key Capture Altitude Text Box Below the "Use Mouse Position for Calculations" check box is a text box labeled "Key Capture Altitude", as you can see in the illustration above. This text box will display the altitude for any point on the map if one has key capture enabled and hits <Ctl>F3 while the mouse is over the selected point. Alternatively, one can type <Ctl>E and the elevation for the map point under the cursor will be continuously displayed as one moves the cursor over the map. This feature is useful for determining the elevation of either the Home or DX station, or of any point on the map when looking for local obstructions or for the best location to site an antenna. This feature, like the path altitude profile feature, requires that SRTM3 files be installed in the appropriate directory. The details of getting and using these SRTM3 files is described by the tool tip obtained by hovering over the "Path Altitude Profile" display, which is labeled as such on the form, and also in the appendix to this document. Hitting <Ctl>F4 will cause a Message Box containing the position and altitude of the point last referenced by hitting <Ctl>F3 to pop up. This is useful if you are cataloging the elevations of several locations on the map.

Manual Parameter Entry Check Box and ReDoCalc Button Beneath the Key Capture Altitude text box are a check box labeled "Manual Param Entry" and a button labeled "ReDo Calc", also seen in the illustration above. Checking the

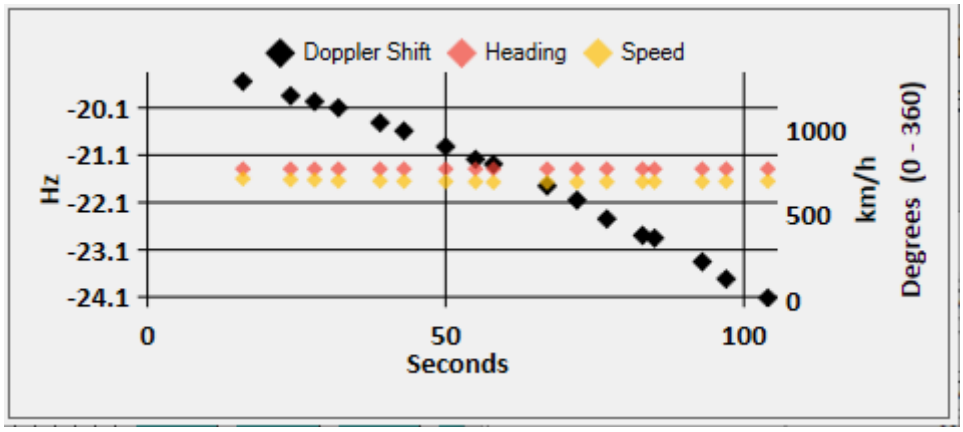
Manual Param check box will allow you to manually enter values for Home and DX Station take-off angles for the inter-station path as well as for the path from each station to the aircraft and also to manually enter parameters for aircraft speed and heading. This is generally done in association with using the mouse to enter theoretical "aircraft" position for calculations. If you check the "Static Mouse Calculations" check box but do not check the "Manual Param Entry" box, then the values for these parameters will be those calculated by the program using the SRTM-3 data and whatever speed, heading, and altitude data were left from the last aircraft selected rather than using manually entered parameters as would be the case if this "Manual Param Entry" box were checked. Because this function is often used for detailed path / location analysis, the results of calculations performed when this box is checked are automatically written to a CSV file at ../Users/your_user_name/AppData/Local/W3SZ/AS_TS_Data.csv, in order to make further analysis easier for the user.

Clicking on the "ReDo Calc" button will redo calculations after parameters have been manually changed as described above.

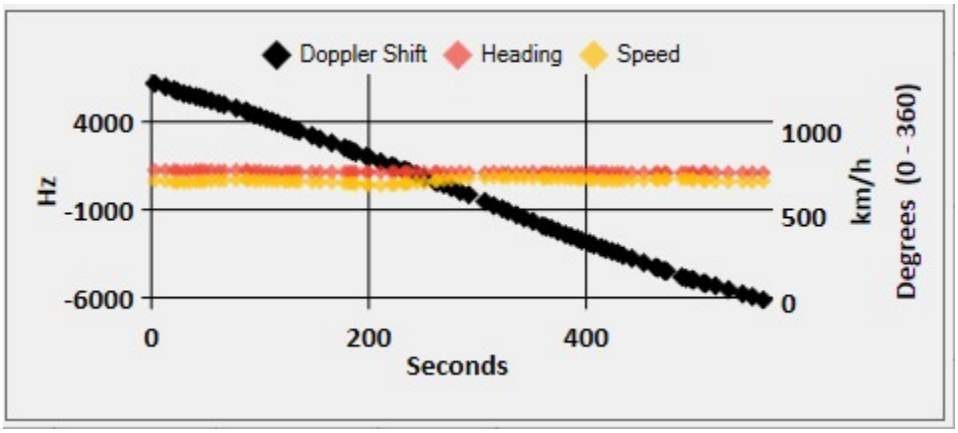
Database Entry Controls To the right of this section are the "Save Plane Data" button which is used to activate or deactivate the saving of all plane data to a file and the "CSV", and "SQLite" radio buttons and the "raw" checkbox. The CSV and SQLite buttons are used respectively to select between CSV file or SQLite database file types for this storage. Saving data to an SQLite database file is the default choice and is strongly recommended. Checking the raw checkbox will save the raw json plane data to a date-and-time-labeled text file in the ...AppData/Local/W3SZ directory.

Local and Remote Plane Server Buttons To the right of this button group, in the "Plane Sources" group box are the buttons used to select whether plane data downloads are from the local RTL1090 server or from a remote internet plane server. These buttons as well as the text boxes described below are also visible in the illustration above. Use of PlanePlotter as a source of aircraft data is deprecated as of version 1.0.9612.40934

Below these buttons in the Plane Sources group box are three text boxes. The leftmost text box, labeled "Local", displays the total number of planes currently "seen" by the local RTL1090 receiver. To the right of this box, the box labeled "Unique" shows the number of these local planes that are "unique" and not "seen" by the internet plane server. The box to the right of this box displays the total number of unique aircraft seen by both the internet and the local plane servers. To the right of this text box is a check box labeled "FAA". Checking this box will add FAA-sourced-time-delayed data to the real-time plane data if the internet plane server being used provides such data.



Doppler Shift Graph Below this area is the Doppler Shift graph, which is shown in the illustration immediately above. This display shows the value of the Doppler shift in Hz on the vertical axis and the time in seconds since the aircraft was selected by the user on the horizontal axis, and is updated each second. Both the X and Y axes for the Doppler Shift display are autoscaling. In this case shown here, the selected aircraft was flying along and parallel to the inter-station path and the frequency band selected for analysis was 10 GHz. You can see in the graph that this geometry results in a very small Doppler shift, ranging from -20 to -24 Hz during the period shown, and also a very small rate of change of the Doppler shift.



Contrast the geometry just described with the Doppler display shown above, obtained from a plane that was flying perpendicular to the direct path between the Home and DX stations Note that the Doppler shift ranges between +6000 and -6000 Hz, and both the shift and its rate of change are far greater than the values shown for the aircraft flying down the inter-station path.

Additional Map Features The map portion of the form has a few features that should be noted. Boundary lines for the Maidenhead grid squares which cover the globe are shown by default. These can be turned off using one of the tabs on the Options form, which is accessed by clicking the Options button at the top left of the main form. A grid square label pop-up for a given grid is activated by

hovering the mouse over the marker placed in the center of that grid. A tab on the options form allows one to turn this function on or off, and to make the grid square center markers more or less visible.

At the top right of the map are controls for zooming the map in and out, labeled "in" and "out", as shown above.

Min Alt 10000 | Min RCS 10

At the lower left edge of the map, shown above, are two boxes that display the minimum elevation, minimum altitude, and minimum RCS selections that the user has made. The default for the minimum altitude and minimum RCS parameters is zero, meaning that no planes will be excluded from display because of their RCS or altitude values In this case the minimum altitude has been set to 10000 feet, so that no planes with altitude less than 10000 feet will be displayed. The minimum RCS in this case has been set to 10, so no aircraft with radar cross sections of less than 10 sq meters will be displayed. When these values are reset, any planes that no longer meet the new limits will be removed from the map, and no new planes that do not meet the new criteria will be displayed. The default value for minimum elevation is minus 10 degrees, making it very unlikely that any planes of interest will be excluded from display by this parameter's value.

These parameters may be set either on the Options page labeled "Limits" or by typing "Alt-A" to reset the altitude limit, "Alt-R" to reset the RCS limit, or "Alt-E" to set the elevation limit. As with other Alt-key and control-key functions in AircraftScatterSharp, the Key Capture button must be active for these keys to perform their functions as just described.

These functions allow the user to "hide" the chaff of smaller planes that will not return a useful signal due to their small RCS, or which are likely flying too low to be able to provide a reflection point that will be above the horizon at both stations, or both.

{Lat=40.7971774151877, Lng=-81.419677734375}

At the lower right edge of the map, shown above, is a box that displays the latitude and longitude for the point on the map over which the mouse is hovering.

If one uses the mouse to hover over an aircraft on the map, information for that plane will pop up in a "ToolTip", whether or not that plane is the "selected" plane. An example of this information is shown above. The displayed information includes:

```
Flight Number  AMX401
Radius to Midpoint  118 km
Flight Distance to Path  108.52 km
Flight Time to Path  09:02
Dist  91/158 km   | Az  115 | Dop 26 Hz   | Skew  110.7
--------------------
Lat   39.9227   |   Lng  -75.0096  |  Elev  4.9 / 2.5
Bearing: 236   |   Speed: 200 m/sec   |   Alt: 8572.5 m
Airframe B738   |   Registr AMX401   | RCS  12
Data Time 02/02/2020 07:09:50 UTC
Depart Mexico   |   Destin Unknown
ICAO hexcode  0D075F
```

Airline flight number on the first line

Radius to the midpoint on the second line

Flight distance to the interstation path on the third line

Flight time to the interstation path on the fourth line

Distances from Home/DX QTH to the aircraft, Azimuth from Home QTH to the aircraft, Doppler shift, and Skew angle on the fifth line.

Plane latitude and longitude and plane elevation from Home/DX locations on the sixth line

Bearing, Speed, and Altitude on the seventh line

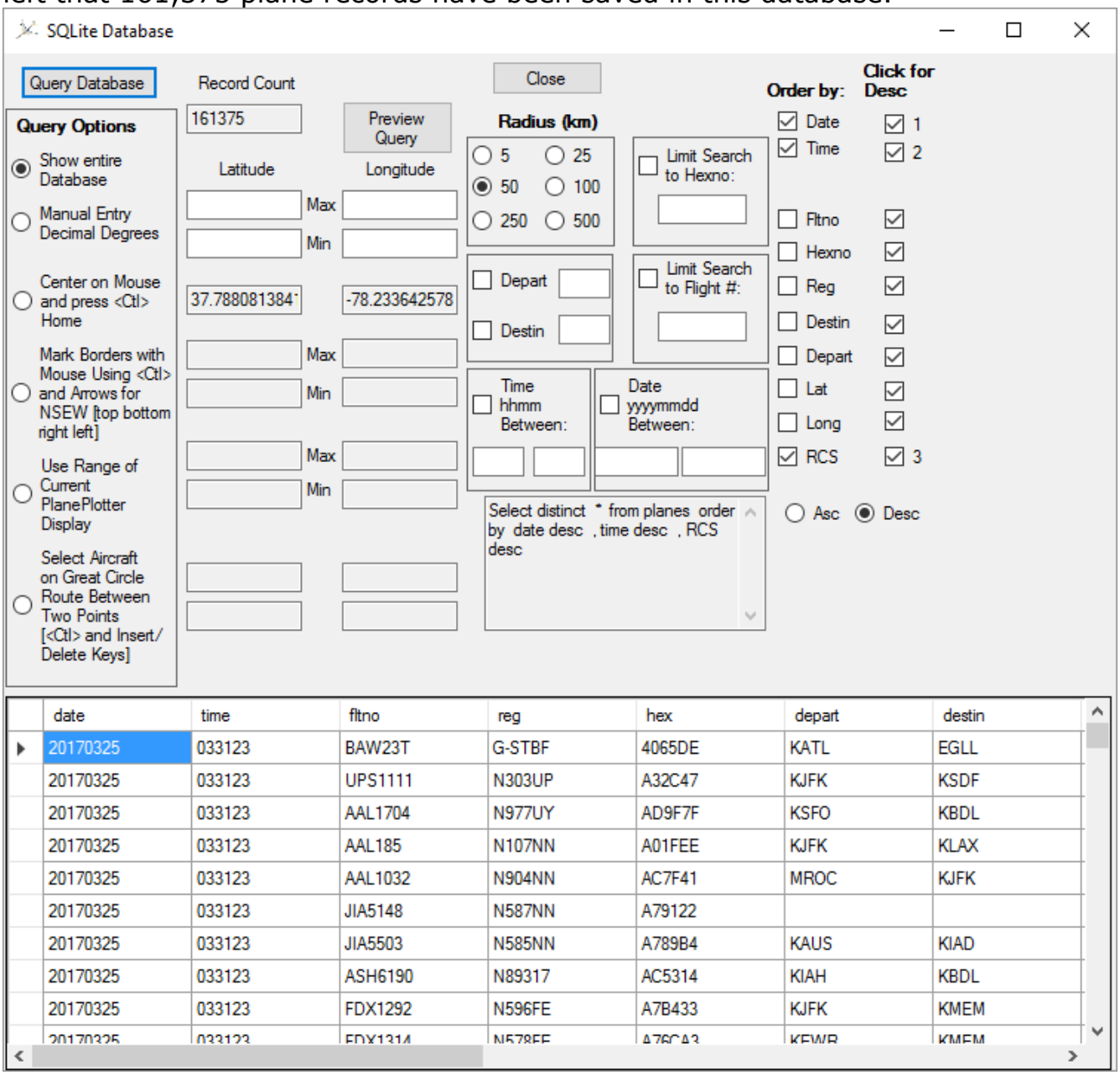
Airframe, Registration, and the estimated RCS for the aircraft, if known, on the eighth line. Aircraft with unknown RCS will display an RCS value of 1, except that all helicopters are identified by assigning them an RCS value of 0.321. It was not possible to estimate helicopter RCS values using publicly available data.

Timestamp for the ADS-B data on the ninth line

Departure Country if using the remote internet plane server on the tenth line

6 digit ICAO Hex Number on the eleventh and final line

VII. Getting Historical Aircraft Position Data. If you are unfortunate enough to live in an area where there is not a constant stream of aircraft between your QTH and that of your QSO partner, making use of the historical aircraft position data that can be acquired by this program may be of great use to you. Below is the SQLite database analysis form that is accessed by clicking on the "SQLite Database" button on the main form of the program. This form shows at the top left that 161,375 plane records have been saved in this database.



Information about each plane that is recorded in the database includes date, time, flight number, registration (whether FAA or other), ICAO hexcode, departing airport, destination airport, latitude of plane, longitude of plane, altitude, bearing, speed, airframe type, squawk, vertical speed, RCS (radar cross section), whether the data is from a local receiver or downloaded from the internet, and the

database ID number of the aircraft. You can see by the check boxes near the top right of this form that the entries in the search that is displayed here were specified to be ordered by date, then time, and then by RCS. The "Query Options" box on the left shows that "show entire database" has been selected, so the table contains all 161,375 planes.

The database is also useful for teaching and demonstration purposes, and for investigational use.

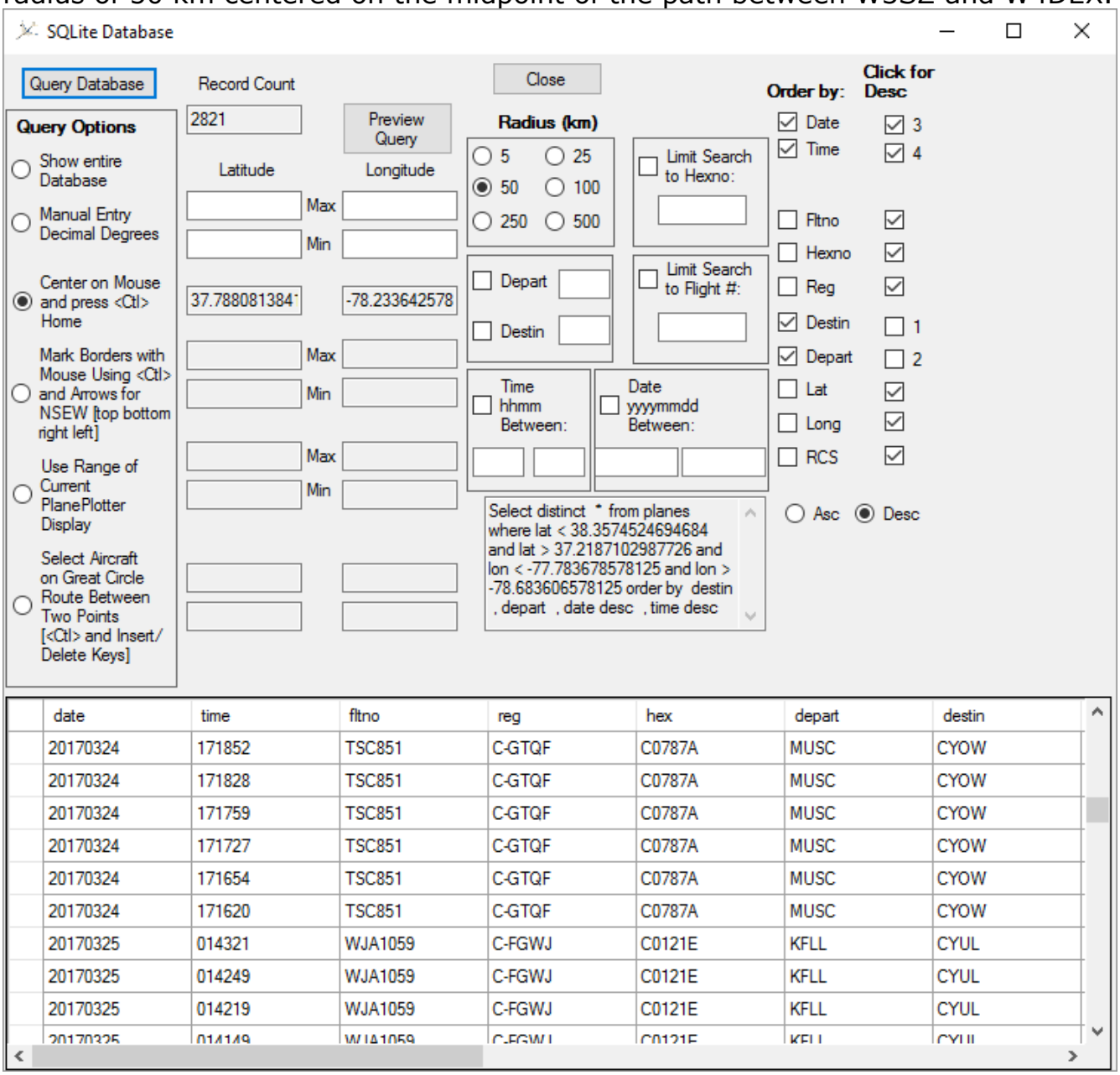
In order to plan an aircraft-scatter session using previously acquired SQL data, one enters the Home and DX station 6-10 digit grid squares into the appropriate text boxes on the primary form and left-clicks the "Set Home and DX Positions" button. That places the direct path line and the midpoint circle and skew lines onto the map, to help one decide on exactly what geographical area to explore with the database. One then opens the SQLite database form by either left-clicking the "SQLite Database" button, thus bringing up the SQLite database form, or by clicking on the "Show Planes from Query on Map" button, which will bring up the SQLite database form and also display the first 200 planes in the selected dataset on the map, where they can be analyzed and viewed just as if they were "live" planes. From the SQLite database form, one can then select a region from which to display aircraft records in one of several ways.

If one wants to see when aircraft are likely to be within a 5, 25, 50, 100, 250, or 500 km square centered on the midpoint of the direct path, one clicks the appropriate radio button on the SQLite database page to set the radius desired. With the key capture function activated, one uses the mouse to place the cursor over the midpoint of the direct path and hits <Ctl>HOME on the keyboard. This puts the coordinates for the midpoint into the appropriate text boxes on the SQLite database page, as shown in the illustration below. One then left clicks the radio button labeled "Center on Mouse and press Home Key" on the database page to choose this method of location selection for the database query, and finally one left clicks the "Query Database" button. This sends the appropriate query to the database, and the data returned to the data grid includes only planes that are within this region. One can order the display of these planes by date, time, etc. as described below and quickly see what aircraft are likely to be available for use, and when.

There are 4 other methods of limiting the geographic region from which planes are returned in the query. These are also contained in the "Query Options" panel and include (1) manual entry of the maximum and minimum latitude and longitude for a rectangle from within which all planes will be selected, (2) setting the borders of a rectangle using the map and the mouse, (3) using the display area of the map itself to set the boundaries, or (4) selecting a great circle route between any two points (such as the Home and DX stations) and using the "Radius" radio buttons to specify a distance from that path from within which planes will be selected.

One can also, and simultaneously, limit the search query by date and/or time, by the ICAO hexno, which is a unique identifier assigned to every plane that is put into service worldwide, and which stays with the plane for its entire life, and by departure or destination airport, and by flight number.

The searches can also have the data returned by the query ordered by up to 10 additional parameters, as you can see on the right side of the Database form.
In the second example shown below we have limited the search to an area with radius of 50 km centered on the midpoint of the path between W3SZ and W4DEX.



This query returns 2821 flight records, and in this case I ordered the query by alphabetically ascending destination, then by alphabetically ascending departure airport, then by descending date, and finally by descending time. Reviewing the

data, you can quickly see that flights crossing this point in this time span included flights from MUSC to CYOW and from KFLL to CYUL. A careful inspection of the "Query Options" portion of the form will show the choices I made to direct the geographic area of the query, and the text box below the time and date check boxes shows the query that the program automatically formed based on the selections I made with just a few clicks of the mouse.

The order of the plane record display can also be changed after the query results have been obtained by clicking on the heading for any column of the display itself.

Viewing SQL Database Planes on the Map Once you have gotten your SQL search organized and sorted in the manner just described, you are ready to view the planes on the map.

To do that, go to the row of buttons between the Selected Aircraft Data area at the top left of the form and the Home and DX Station position entry portion of the display below that. This row of buttons is pictured below:

Then click on the "Show Planes from Query on Map" and the program will display up to 200 planes at a time on the map.

If there are more than 200 planes in the query results, how you sorted the planes in your query becomes important. For example, if you want to follow the course of a single plane in the SQLite database during a single flight, then you would want to do a search with hex number ("hexno") as the first search term, date as the second search term, and time as the third search term. This would make it most likely that all of the plane entries for each flight would be shown on the same map page.

When there are more than 200 planes you can view successive sets of 200 planes by clicking on the "Up 200" button, as shown above. If, after doing this, you want to return to a map page that you had previously viewed that is nearer to the beginning of your query than your current map view, you would click the "Dn 200" button.

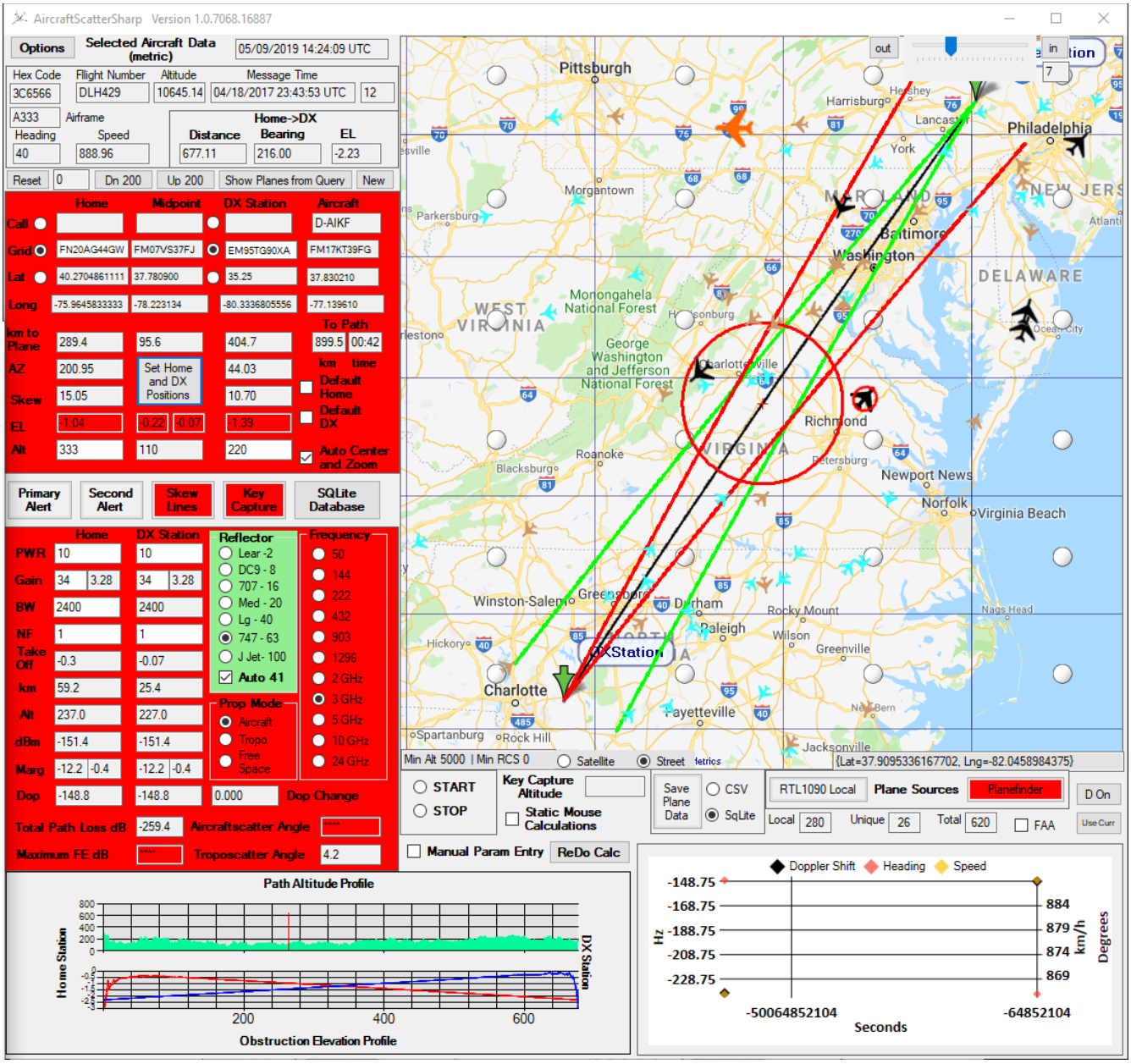
As you cycle through the multiple map displays available for a large query result, you can tell where you are in the data set by looking at the number displayed in the text box between the "Reset" button and the "Dn 200" button. This number represents the index of the first plane on the currently displayed map; if the number is 0, then you are looking at the first 200 planes in your query. If the number is 200, then you are looking at the second 200 planes, etc.

Clicking the "Reset" button returns the display index back to zero and initiates a

new query. If you have entered a new query before you click this button, then the first 200 planes in the new query result will be immediately displayed when you click this button.

At the extreme right end of this row of buttons is the “New” button. Clicking this button signals that a new plane is going to be used for Doppler calculations using planes data from the SQLite database. Clicking this clears the Doppler graph and ensures that the time stamp of the next plane marker to be clicked will be used as the "start" time for subsequent Doppler calculations.

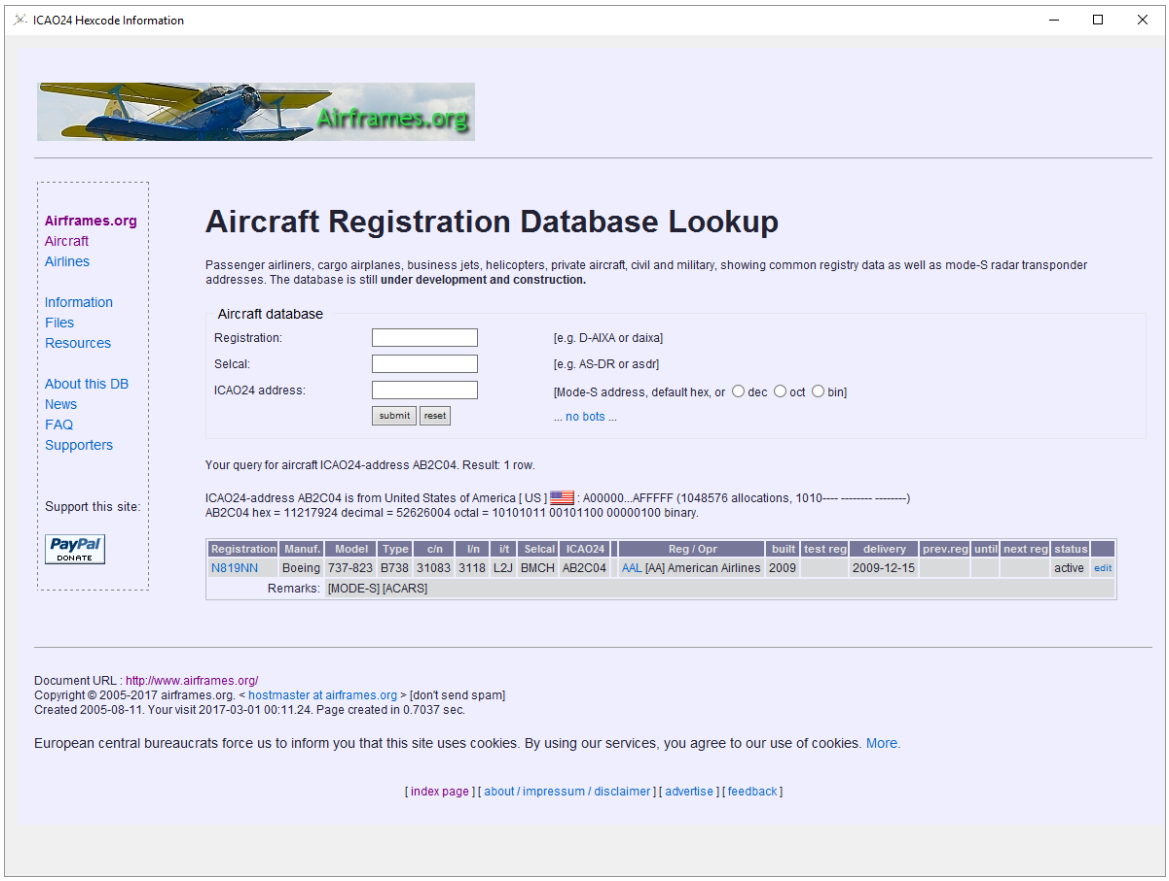
Now lets review in more detail the results of clicking the “Show Planes from Query” button in this case.



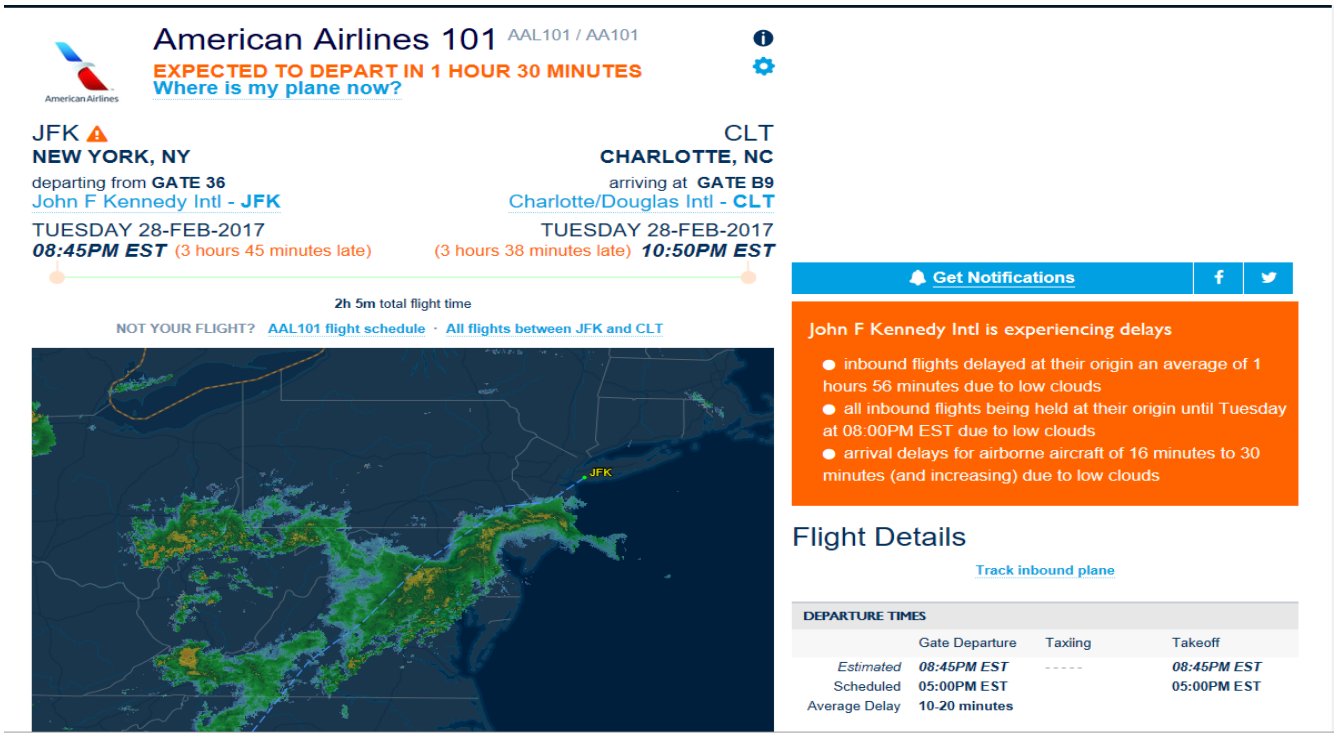
The display looks just like a live plane display, but you can see that the selected plane has an ADS-B timestamp that is 2 years prior to the time displayed in the current time display.
In the data and calculation area to the left you can see all of this plane's position and RF calculation parameters and even the Doppler data, just as if it were a "live" plane.

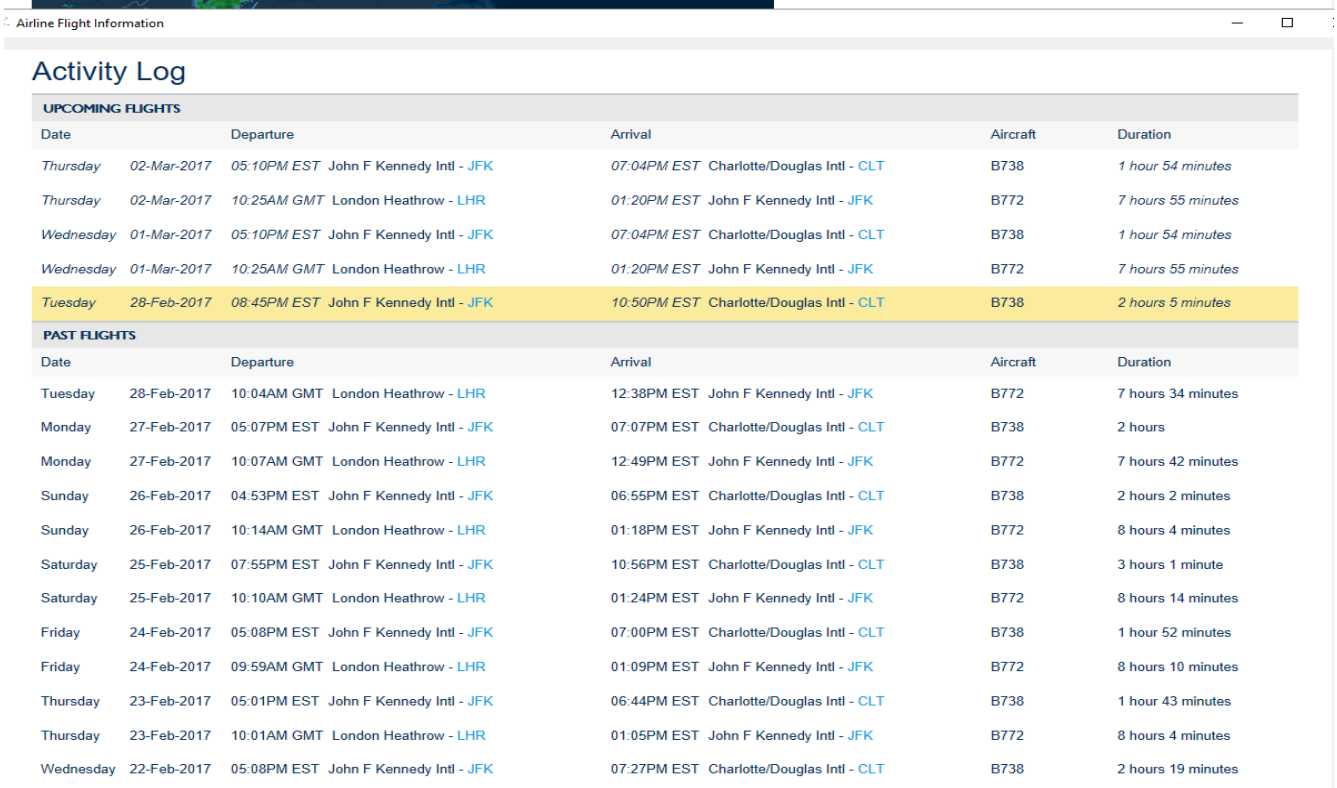
You can get more information about a plane on the map that you have selected, whether it is "live" or a plane from the SQLite database, by typing <Ctl>F7, which will bring up information for its hexno from the web pages at airframes.org. Such a result is shown immediately below. To do this you need to register with a user name and password at http://www.airframes.org/signup. Then click the "Options" button at the top left corner of the main AircraftScatter# window. Next click the "URLs/IPs" tab and enter your airFrames.org user name and password and click "OK". Once you have entered this data it will be remembered by AircraftScatter# and you never need to re-enter it unless your airFrames.org account expires due to 45 days or more of non-use.

The first time you type <Ctl>F7 during a session after having selected an aircraft, AircraftScatter# will log on to airFrames.org and present a browser window. Keep that window open so that you stay logged on, and the next time you select a new aircraft and then type <Ctl>F7 and thereafter the aircraft information will be displayed on this web page.



By clicking <Ctl>F8 you can bring up flight information for the selected aircraft from FlightAware.com, as shown below. This gives you a history of several weeks of arrival and departure times that you can use to get an idea of how much variability there is in flight times, to supplement the data you acquired with Aircraft Scatter Sharp. Note that if you are using a plane that was captured by the SQL database a really long time ago, that the airline might have reassigned the flight number to a different route.





Because plane schedules are NOT like clockwork, using only published schedules to estimate when a plane will be in a given area can be unreliable. But using Aircraft Scatter Sharp to gather large amounts of data over a period of days or weeks or longer allows one to make statistically based decisions on when aircraft of appropriate RCS and altitude are most likely to be in the region of interest, by examining the historical data obtained using this program. Using the various functions on the database form, one can select which data is to be displayed, and by analyzing that data, one can then devise operating schedules that will be most likely to be productive. Also, the data in the SQLite dataset is useful for quickly testing experimental hypotheses about the effects of various aircraft parameters on various dependent variables, and for teaching and demonstration purposes.

VII. SRTM-Based Peak Finding and Longley-Rice Attenuation Maps

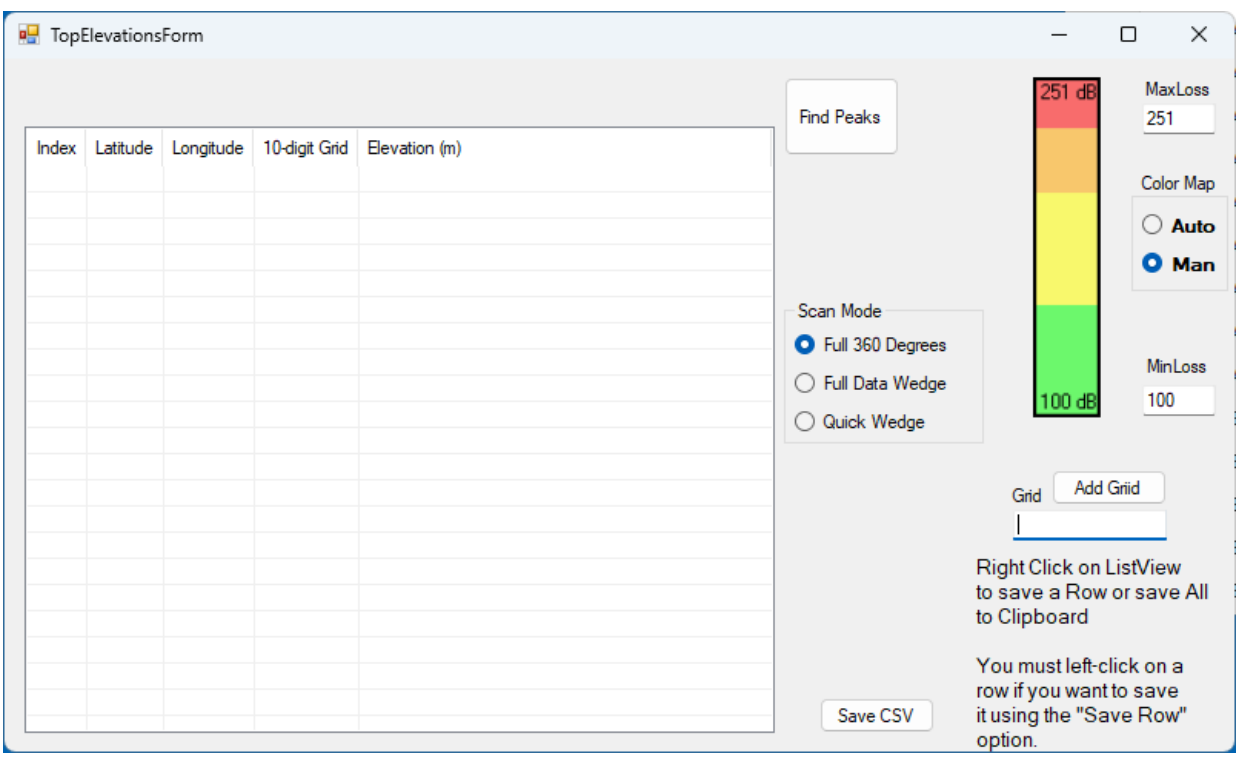
The SRTM data files that are used for troposcatter calculations and showing the path altitude profile on the main form are also of great value in peak finding and creating attenuation plots. To access these functions you type <Alt>P. Note that in order to make use of the Alt and Ctl-associated key commands you must have the "Key Capture" button activated. The Alt-associated commands uniquely associated with the peak-finding and coverage map functions are:

<Alt>P which displays a second form for finding peaks and creating Longley-Rice ITM method-based attenation plots.

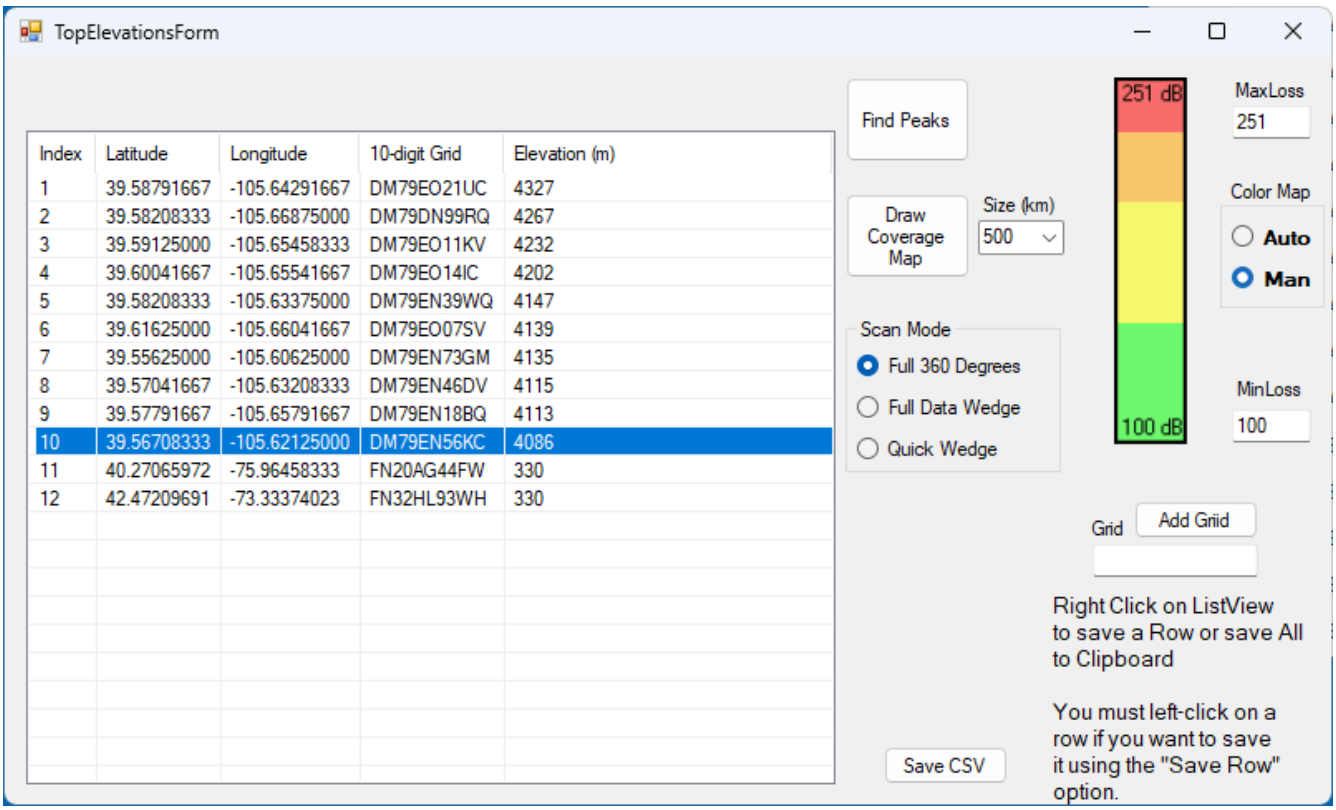
<Alt>C which erases the coverage plots and markers placed by the Longley-Rice-related methods.

<Alt>Q which terminates a peak-finding or Longley-Rice-based calculation.

Typing <Alt>P will bring up a daughter form that initially looks like this:



In order to perform peak finding you first need to mark the rectangle of interest on the map by using Ctl-UpArrow, Ctl-DownArrow, Ctl-RightArrow, and Ctl-LeftArrow to mark respectively the North, South, East, and West borders of your rectangle of interest. The larger the rectangle, the longer the calculation will take. On my XEON a 10 x 10 km square takes about a second. To start the calculation left-click the "Find Peaks" button near the top right corner of the chart display form. When the calculations have finished the form will look something like what you see below, with the 10 highest peaks shown in order of descending elevation, numbered from 1-10 and with the latitude, longitude, 10-digit grid, and elevation displayed for each peak. The 11th entry gives the elevation of the "Home" station and the 12th entry gives the elevation of the "DX" station. If you type Ctl-M before doing these calculations, then a row 13 will be added for the location on the map that was under the mouse cursor when you typed Ctl-M.



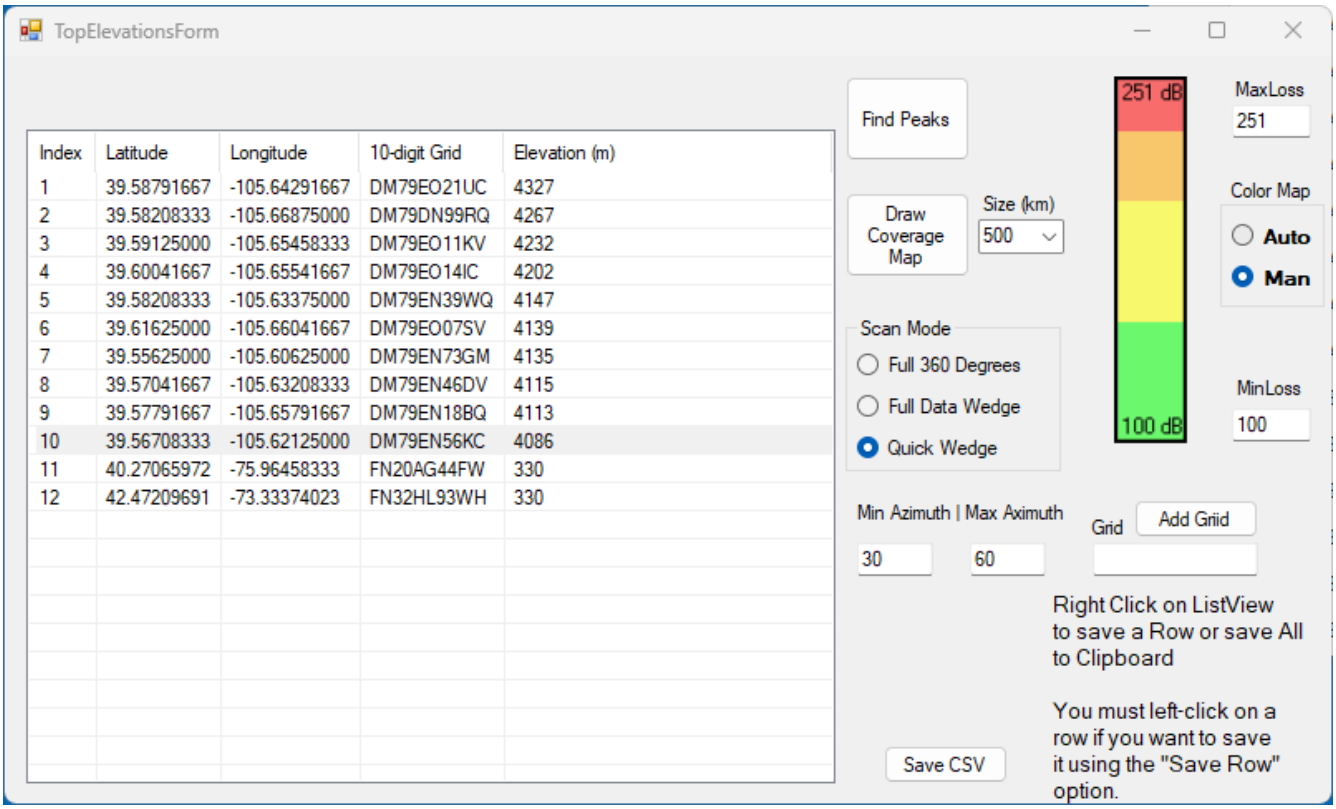
Index	Latitude	Longitude	10-digit Grid	Elevation (m)
1	39.58791667	-105.64291667	DM79EO21UC	4327
2	39.58208333	-105.66875000	DM79DN99RQ	4267
3	39.59125000	-105.65458333	DM79EO11KV	4232
4	39.60041667	-105.65541667	DM79EO14IC	4202
5	39.58208333	-105.63375000	DM79EN39WQ	4147
6	39.61625000	-105.66041667	DM79EO07SV	4139
7	39.55625000	-105.60625000	DM79EN73GM	4135
8	39.57041667	-105.63208333	DM79EN46DV	4115
9	39.57791667	-105.65791667	DM79EN18BQ	4113
10	39.56708333	-105.62125000	DM79EN56KC	4086
11	40.27065972	-75.96458333	FN20AG44FW	330
12	42.47209691	-73.33374023	FN32HL93WH	330

You can add additional lines to the chart by typing a Maidenhead grid value into the grid text box near the right edge of the form and then left-clicking the "Add Grid" button. Then, the Latitude, Longitude, grid, and elevation will be displayed.

Notice that once you have populated the chart with at least one dataset, two additional contros appear, the "Draw Coverage Map" button and a drop-down menu marked "Size (km). Left-clicking the coverage map button will start the Longley-Rice calculations, and the size menu is used to select the radius of the attenuation plot for distances between 20 and 500 km. The larger the radius, the longer the calculations will take to complete. In addition to full 360-degree

scans, you can select a “full data wedge” or a “quick wedge”. Doing a “quick wedge” scan in the direction of interest will markedly reduce the time required for the calculations to complete.

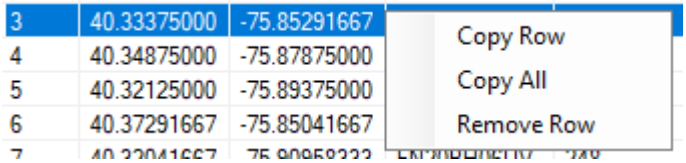
If you select either the full or quick wedge, then an additional set of controls appears so that you can set the minimum and maximum azimuth, as you can see below:



Index	Latitude	Longitude	10-digit Grid	Elevation (m)
1	39.58791667	-105.64291667	DM79EO21UC	4327
2	39.58208333	-105.66875000	DM79DN99RQ	4267
3	39.59125000	-105.65458333	DM79EO11KV	4232
4	39.60041667	-105.65541667	DM79EO14IC	4202
5	39.58208333	-105.63375000	DM79EN39WQ	4147
6	39.61625000	-105.66041667	DM79EO07SV	4139
7	39.55625000	-105.60625000	DM79EN73GM	4135
8	39.57041667	-105.63208333	DM79EN46DV	4115
9	39.57791667	-105.65791667	DM79EN18BQ	4113
10	39.56708333	-105.62125000	DM79EN56KC	4086
11	40.27065972	-75.96458333	FN20AG44FW	330
12	42.47209691	-73.33374023	FN32HL93WH	330

Additional controls are the “Save CSV” button near the lower left corner that saves the chart to a csv file, and the “MinLoss” and “MaxLoss” text boxes and the Color Map Auto and Man buttons that are located to the right of the color bar that shows the coloring vs dB attenuation scale used by the attenuation map. If the Auto button is engaged, then the routine determines the limits of the color scale. If the Man button is engaged, then the values placed by the user in the MinLoss and MaxLoss boxes are used. I generally use the manual setting with a range of 100-250 dB.

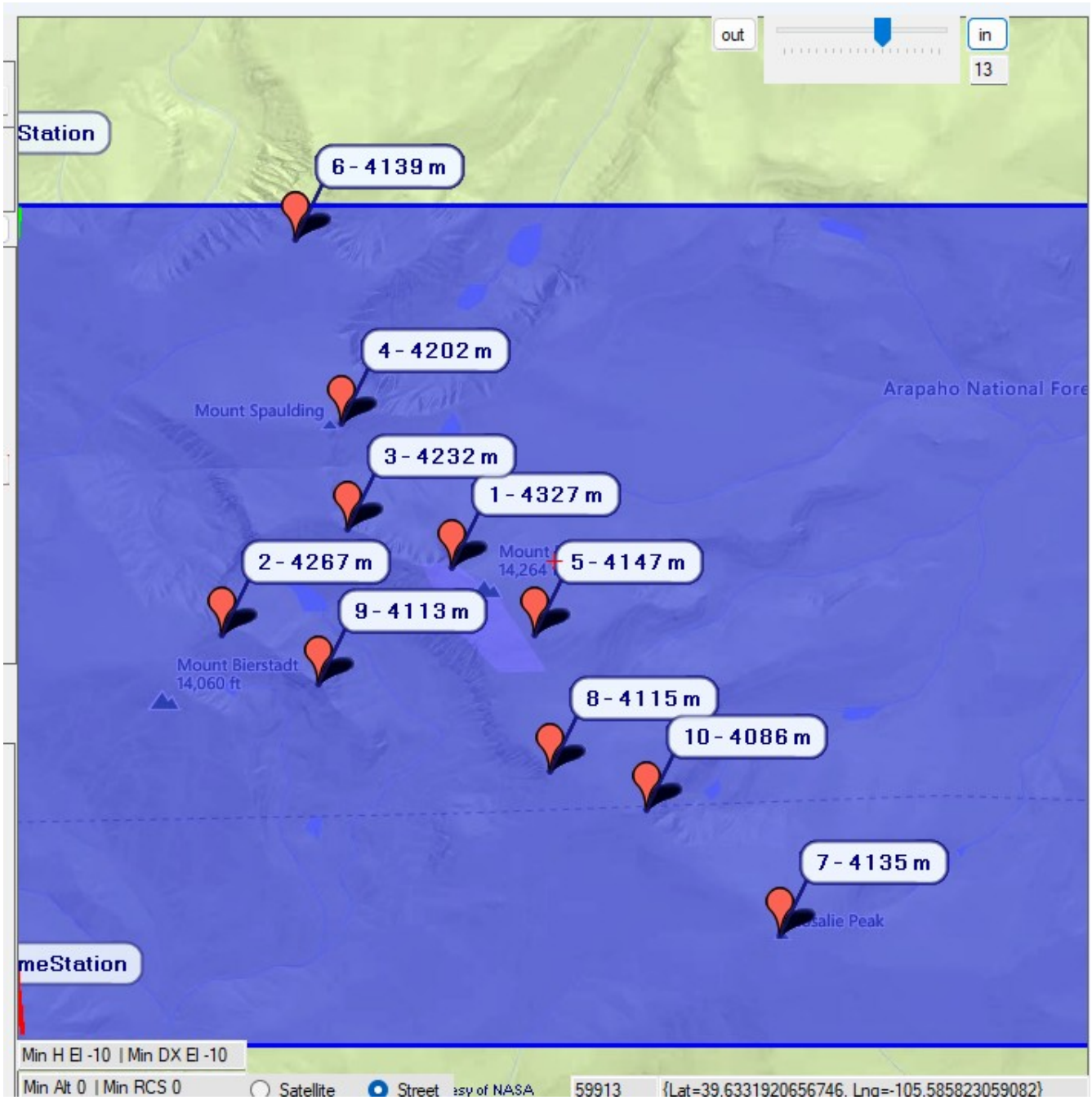
Additionally, right-clicking on any row of the table of lat/long/grid/elevation values will display a context menu that when clicked will save the contents of that row to the clipboard, remove that row, or save the entire table to the clipboard as you can see below:



3	40.33375000	-75.85291667
4	40.34875000	-75.87875000
5	40.32125000	-75.89375000
6	40.37291667	-75.85041667

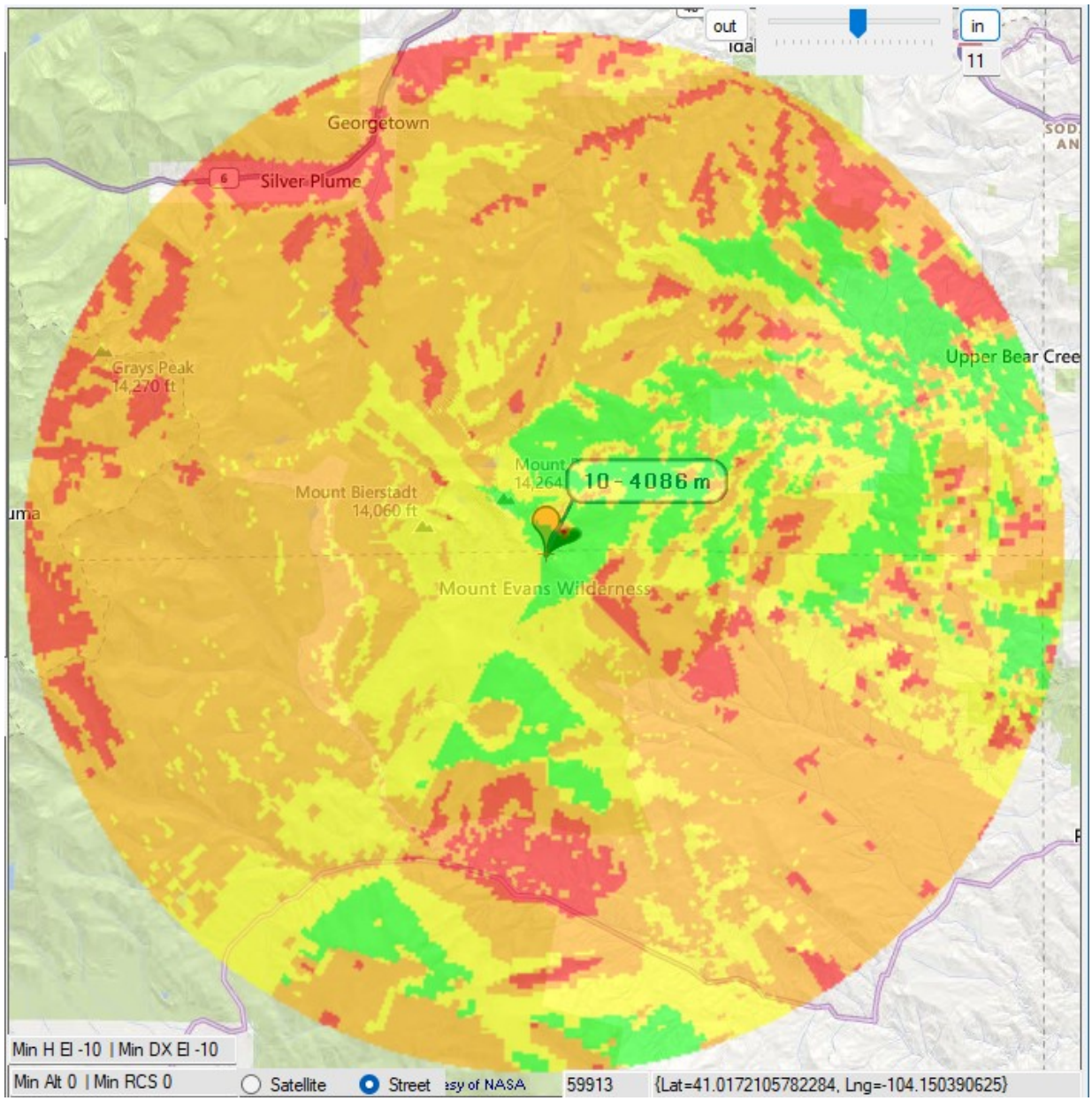
Copy Row
Copy All
Remove Row

When you click "Find Peaks", in addition to getting the tabular display on the daughter form as shown above you also see the peaks displayed on the map on the main form with each peak labeled with its rank and elevation in meters. This is shown in the image below .In addition to the labeled peaks the map also shows the selected area rectangle shaded in blue with darker blue boundaries:



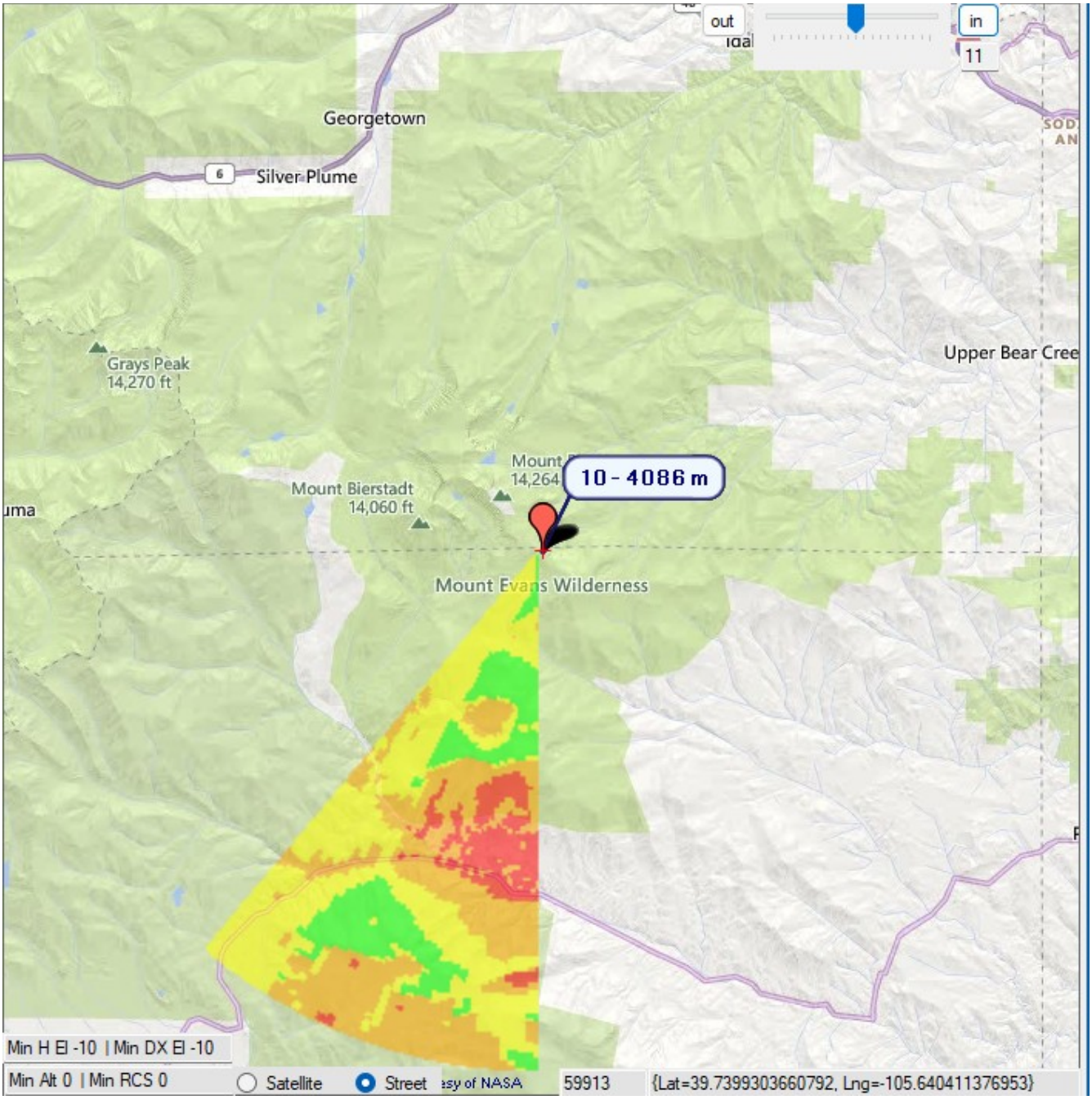
To get an attenuation plot for any of the displayed peaks, just left-click on the row containing the peak to select that row and then click the "Draw Coverage Map" button. The calculations will be done for whatever frequency you have selected using the frequency radio buttons that are located just to the left of the left map border on the main display. It is best to start with smaller radii like 20 km until you know how long the calculations will take on your computer. Here on my old XEON a 20 km 360-degree scan takes 30 seconds. A quick wedge scan using the same 20 km radius takes less than 3 seconds.

Below is an image using peak 10 from the above table/map image as the transmitter. You can see that the mountainous terrain here (between Denver and Breckenridge, CO) leads to substantial inhomogeneity in attenuation.



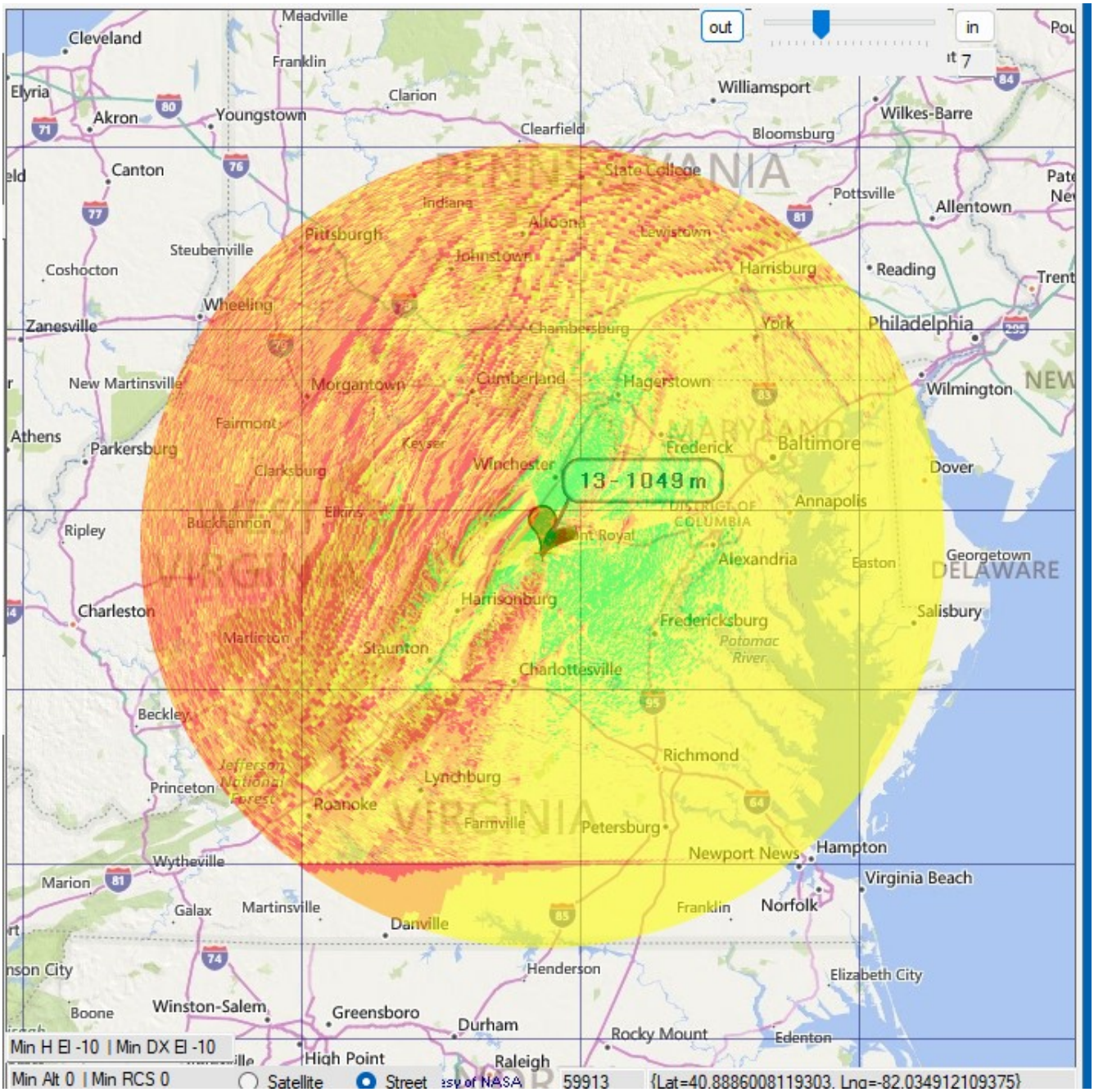
For all of the examples in this document a frequency of 10 GHz was used.

A sector scan taken from 180-220 degrees using the quick wedge setting is shown below This took less than 4 seconds to create. You can see that even though the calculation time was markedly reduced, the details for the visualized sector are well preserved with the quick scan. Wisely using the quick scans instead of always using 360 degree scans can save substantial time.

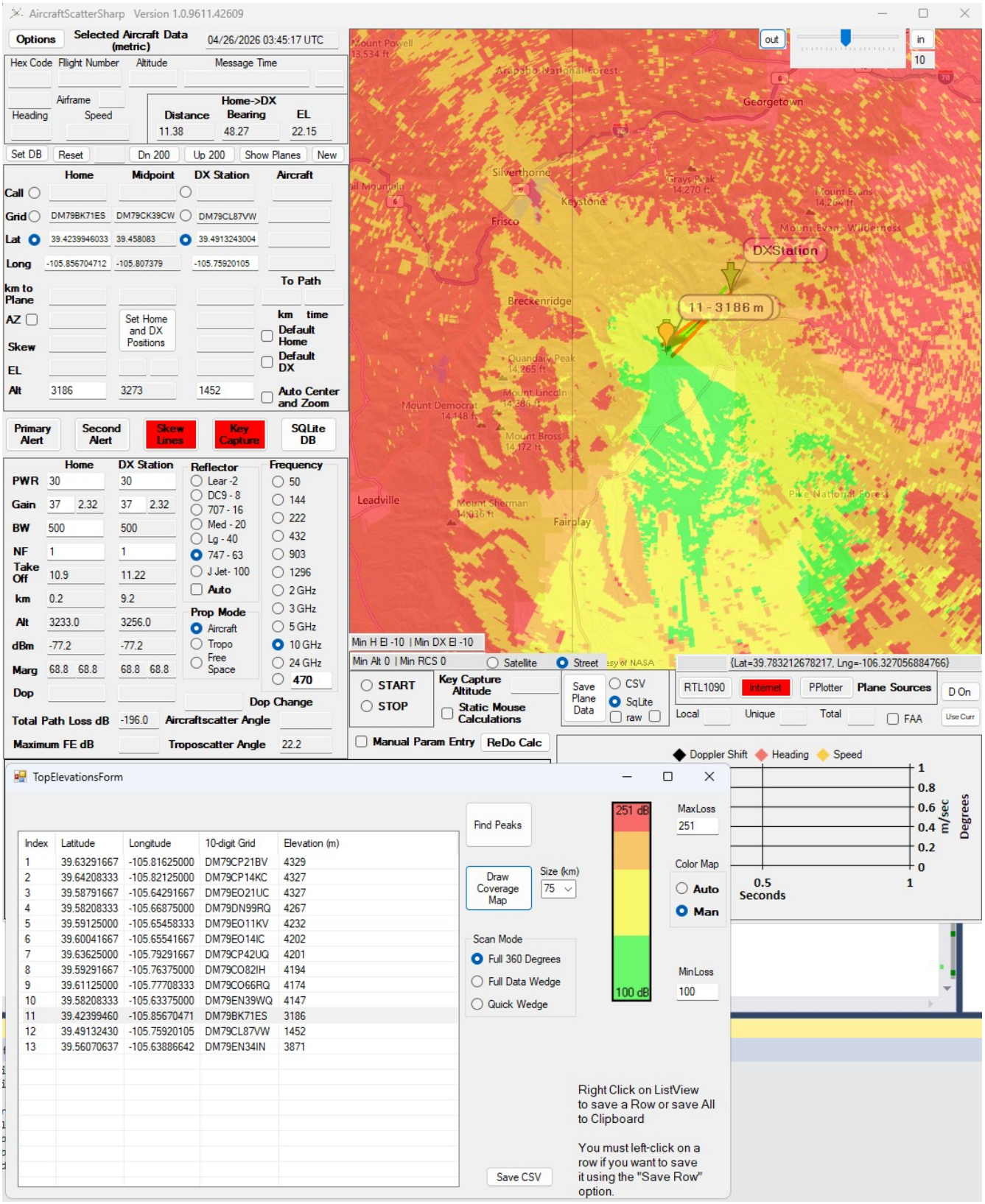


A few example attenuation plots are shown below. The first is from Hogback, FM08US72AU, taken with a 250 km radius and full 360 degree scan. You can see that this particular Hogback site has lower attenuation for paths with azimuth

~45-200 degrees than it does to the West and North.



Below is another scan from the area in Colorado between Breckenridge and Denver. For this example, as you can see, a peak that was well below the elevation of the higher peaks in the region was selected. You can see that this causes propagation to be largely limited to azimuths between ~135 and 220 degrees:



Index	Latitude	Longitude	10-digit Grid	Elevation (m)
1	39.63291667	-105.81625000	DM79CP21BV	4329
2	39.64208333	-105.82125000	DM79CP14KC	4327
3	39.58791667	-105.64291667	DM79EO21UC	4327
4	39.58208333	-105.66875000	DM79DN99RQ	4267
5	39.59125000	-105.65458333	DM79EO11KV	4232
6	39.60041667	-105.65541667	DM79EO14IC	4202
7	39.63625000	-105.79291667	DM79CP42UQ	4201
8	39.59291667	-105.76375000	DM79CO82IH	4194
9	39.61125000	-105.77708333	DM79CO66RQ	4174
10	39.58208333	-105.63375000	DM79EN39WQ	4147
11	39.42399460	-105.85670471	DM79BK71ES	3186
12	39.49132430	-105.75920105	DM79CL87VW	1452
13	39.56070637	-105.63886642	DM79EN34IN	3871

Further suggestions on how to setup and use Aircraft Scatter Sharp are contained in the appendix, which immediately follows this page.

If you have any questions, please contact me by email at mycall at comcast dot net. You may download a copy of the program from the web page listed below.

There is also a copy of this paper plus additional information at https://w3sz.com/AircraftScatter.htm

Roger Rehr W3SZ
04-26-2026

Appendix. Suggestions for getting started.

1. The program has been tested and works with Windows 7, 8, 8.1, 10, and 11, both 32 and 64 bit versions. It has not been tested with other operating systems.
2. Download Aircraft Scatter Sharp from: https://w3sz.com/updates/AircraftScatterSharp.exe
3. Double-left-click the file to start the installation process.
4. Make the usual appropriate responses to prompts that apppear to install the program.
5. When the program starts it will tell you that it is writing to disk the initial dBplanes.sqlite database file and the call3.txt file. It will also check to see if you are running the newest version of the program and if not, it will ask you if you want to install the newest version.
6. Go to Options by clicking the "Options" button at the top left of the main form. If you are using an RTL 1090 for input, enter its URL on the URLs/IPs tab. On the URLs/IPs tab also enter your airFrames user name and password so that you can use Cntl-F7.

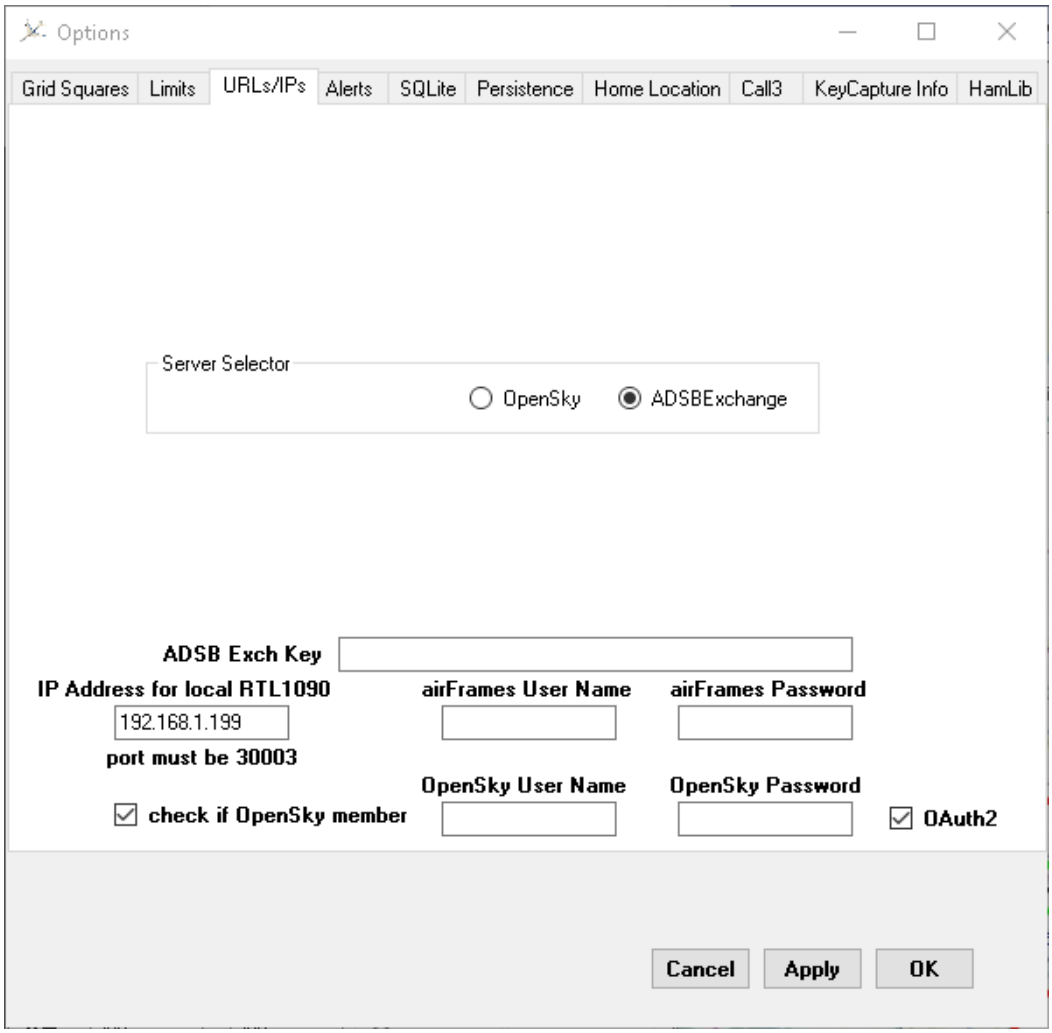
As of August 2025 the preferred plane server option is ADSB Exchange https://www.adsbexchange.com/. To use ADSB Exchange with AircraftScatterSharp you need to sign up for the ADSB Exchange RapidAPI, which you can do from https://rapidapi.com/adsbx/api/aircraftscatter/. There is additional information on how to get your key at this url: https://w3sz.com/obtainADSBExchAPI_AirScatterSharp.html Signing up will give you 60,000 downloads per month, which is equivalent to you get from OpenSky when you upload enough planes per month to put you in OpenSky's "Active Contributing User" class. When you sign up with ADSB Exchange you will be assigned an X-RapidAPI-Key which is a roughly 50-digit alphnumeric string that you will need to enter into the text box labeled "ADSB Exch Key" on the AircraftScatterSharp Options tab labeled URLs/IPs in order to access the ADSB Exchange planeserver. There is no charge for using the ADSB Exchange RapidAPI.

OpenSky is another option for plane server. On the URLs/IPs tab you can also enter your OpenSky Network username and password and check the OpenSky member box. If you aren't already registered as an OpenSky user but you want to use OpenSky, then set up a (free) account there now at https://opensky-network.org/ Currently as of August 2025 there are two methods for OpenSky authentication, classic and Oauth2. At some point in the near future classic authentication will be phased out. To use the newer OAuth2 authentication, check the box labeled "OAuth2" on this tab. OAuth2 use with OpenSky is explained at https://openskynetwork.github.io/opensky-api/rest.html#oauth2-clientcredentials-flow. If you aren't an OpenSky registered user, then you are limited to 400 API download credits per day. If you are an authenticated user, then you are granted 4000 API download credits per day. If you are a contributing user with at least 30% online percentage in the past month, then

you are granted 8000 API download credits per day. How long these allotments of API downloads will last you depends on the download interval that you specified on the Options >> Persistence tab and how large an area you query (calculated as square degrees). If you set the download interval to 10 seconds and download less than 25 square degrees, then 100 download credits will last you about 17 minutes, 1000 will last you about 2.75 hours and 2000 will last you about 5.5 hours. If you set the download interval to 60 seconds, then 100 download credits will last you an hour and 40 minutes, 1000 will last you about 16 hours and 40 minutes, and 2000 will last you about 33 hours and 20 minutes. Since the download counter resets every 24 hours, if you are a contributing user and set the download interval to 60 seconds then you will likely never run out of downloads, unless you are querying a large area. If you aren't a registered OpenSky user, you will quickly run out of API downloads regardless of the download interval that you choose.

The number of remaining download credits that you have appears in a textbox at the bottom of the map, just to the right of center and to the left of the Lat/Lng textbox as you can see in the image below. This value is updated every time a query is made to the plane server. When you are using the OpenSky plane server, this number is the number of remaining download credits that you have for the current day. When you are using the ADSB Exchange plane server, this number is the number of remaining download credits that you have for the current month. These intervals are chosen because OpenSky download credits roll over every day, whereas ADSB Exchange download credits roll over every month.

The “URLs/IPs” tab that was discussed in the above text is shown below:



7. While on the Options form, you should also go to the “Home Location” tab and set the home latitude, longitude, and altitude for your QTH, and a DX station if you have a regular DX partner. After you have entered the appropriate data, click the “Set Home Station” button on this tab (and also the “Set DX Station” if you have entered location and altitude data for the DX station). You should also enter the mast heights for both your station and the DX station, if known. Then click “OK” to close the Options form. The default values for the parameters on the other Options pages will be suitable until you gain more experience. Images of the Options pages with additional information regarding their use appear at the end of this appendix.
8. There are numerous tool tips which appear when you hover over the various controls, text boxes, etc. to guide you as you learn the program.
9. After you have selected your plane server(s), you can start downloading plane data from the internet by left-clicking the “START” button near the center of the main form below the map.
10. Buttons turn RED when activated, and return to their baseline color when deactivated.
11. Using the internet plane server is selected by default. You can deselect it

by clicking on the “Internet Servers” button. When you exit the program, your choice will be remembered. If you select “Internet”, it will deselect “Pplotter”, and vice versa. You can run RTL1090 while running one of the other two choices too.

12. You can additionally select to display local plane data, sent using the port 30003 server of your RTL dongle software, by clicking on the “RTL1090 Local” button.

13. To save plane data to the SQLite database, click the “Save Plane Data” button.

14. Hover over a plane with the mouse to see its tool tip data. You need to hover near the “3 o'clock” to “6 o'clock” quadrant below the plane to activate the tool tip, and this is also where you need to left-click to select an aircraft. It takes some practice to select the correct aircraft when the planes are clustered close together.

15. Left-click a plane to make it the “selected” plane and put all of its data into the data/calculation portion of the main form. As just noted, you need to click near the “3 o'clock” to “6 o'clock” quadrant below the plane to select it.

16. In order to use the Hotkeys, you need to turn on key capture, using the “KeyCapture” button near the middle of the data/calculation portion of the main form. The hotkeys are F1-F9 combined with the <Ctl> key and do the following:

<Ctl>F1 will place the latitude and longitude of the point under the mouse cursor in the Home Station position boxes, **<u>if</u>** the manual entry “Lat” radio button is selected for the Home Station.

<Ctl>F2 will place latitude and longitude of the point under the mouse cursor in the DX Station position boxes, **<u>if</u>** the manual entry “Lat” radio button is selected for the DX Station.

<Ctl>F3 will place the altitude of the point under the mouse cursor into the Key Capture Altitude text box beneath the map.

<Ctl>F4 Displays a message box showing Latitude, Longitude, Altitude, and Grid for the point chosen when the F3 key was last used as described above.

<Shift>F4 is equivalent to **<Ctl>F3** followed immediately by **<Ctl>F4**.

<Ctl>F5 Activates ToolTips for all forms.

<Ctl>F6 Deactivates ToolTips for all forms.

<Ctl>F7 Brings up a web page showing information for the selected plane’s ICAO 6-digit hexadecimal identifier. For this you need to register at airFrames.org.

<Ctl>F8 Brings up a Flight Aware web page showing both current and historical information for the selected plane’s Flight Number.

<Ctl>F9 Shows a list of all Key Capture functions.

<Alt>A Allows user to set a lower altitude limit for planes displayed.

<Alt>E Allows user to set a lower limit for the elevation as seen by either station for the planes displayed.

<Alt>R Allows user to set a lower RCS limit for planes displayed.

<Alt>M Turns on or off display in the Key Capture Altitude box of the elevation in meters of the map point under the mouse cursor.

<Alt>P Displays a second form for finding peaks and creating Longley-Rice

ITM method-based attenation plots.

<Alt>C Erases the coverage plots and markers placed by the Longley-Rice-related methods.

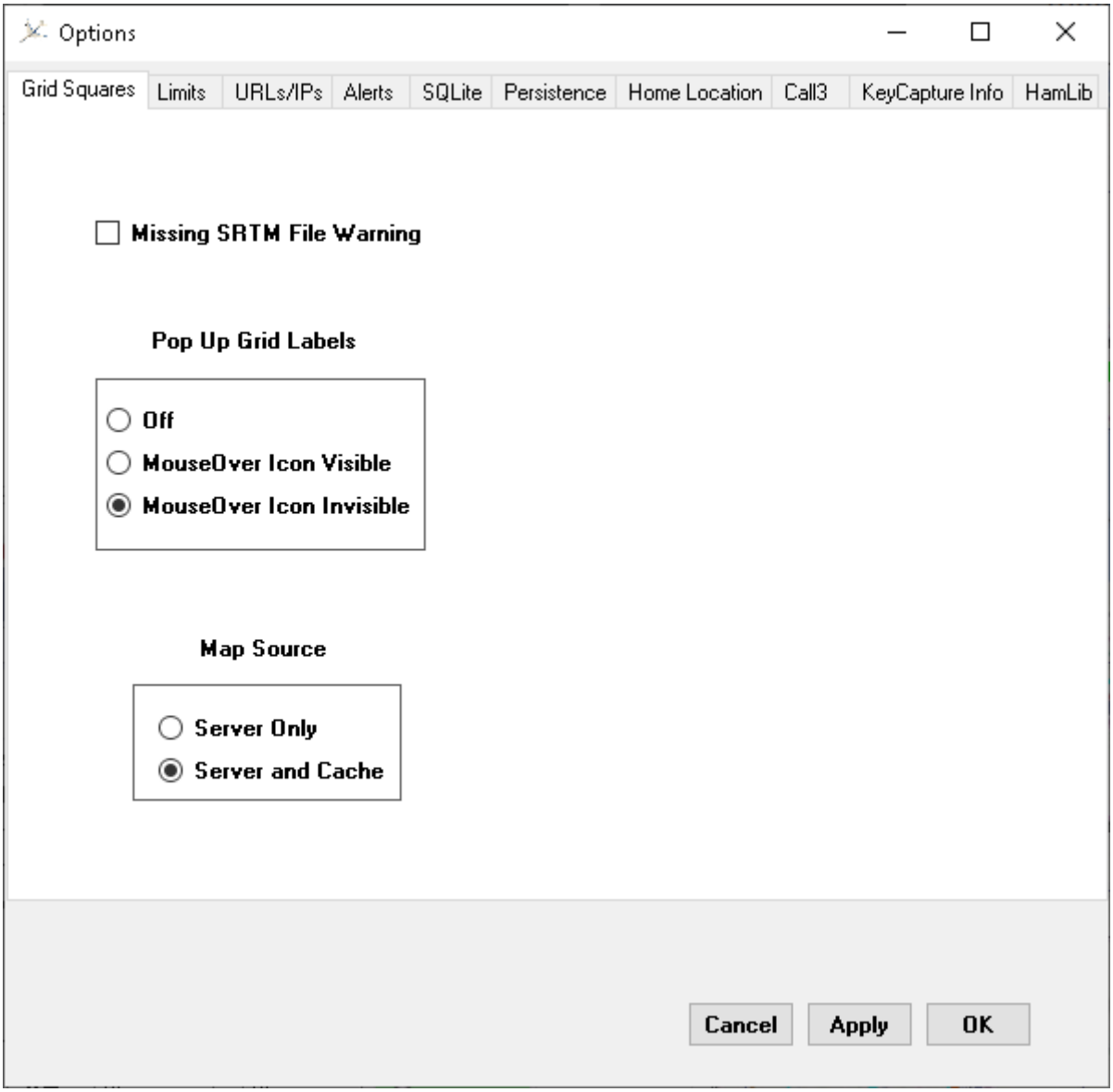
<Alt>Q Terminates a peak-finding or Longley-Rice-based calculation.

<Ctl>Home Used on the SQLite database page to center a database query around a geographic point on the map.

<Ctl>Insert and **<Ctl>Delete** Used on the SQLite database page to set two ends of a Great Circle path along which a database query will return planes.

<Ctl>Up-Down-Right-Left Arrows Used on the SQLite database page to set North/South/East/West boundaries for a rectangular query box.

17. Zoom the map in and out using the "in" and "out" buttons at the top right of the map.
18. You may drag the map to a new center by holding down the right mouse button while you are dragging the map with the mouse pointer.
19. If you have "Auto Center and Zoom" checked [the default] then each time you click "Set Home and DX Positions", the map will center itself on the midpoint of the path you have created.
20. You can enter Home and DX station position data one of 3 ways:
    - Click on the "Call" radio button and type in a call. If that call is contained in the call3.txt database, its grid and Lat/Long information will be entered.
    - Click on the "Grid" radio button and type a 4-10 digit grid locator
    - Click on the "Lat" radio button and enter the latitude and longitude values
21. Once you have entered the position data for Home and DX stations as described above, left-click the "Set Home and DX Positions" button to calculate the path between the home and DX stations.
22. The Path Altitude Profile will only be displayed if you have downloaded all of the necessary SRTM3 data files from https://srtm.kurviger.de/SRTM3/North_America/index.html and put it into the %localAppData%/W3SZ/ElevationData/SRTM3 directory. This is most likely of the form x:/Users/your_user_name/AppData/Local/W3SZ/ElevationData/SRTM3/.
23. If you check the checkbox next to the "AZ" label in the Station and Aircraft Position Data area, and if you have configured the rotor settings properly in the Options "HamLib" tab, then your antenna will track the position of the selected plane. You can set the rotor "time out" or "dead zone" to be any number of degrees greater than 0.1. This feature uses the N1MM Rotor Control App, and you can read about setup for that in the N1MM documentation.
24. Read the tool tips and the Options pages for more useful information.
25. I have reproduced the Options pages from my installation below, in case you have trouble reading them at your site:

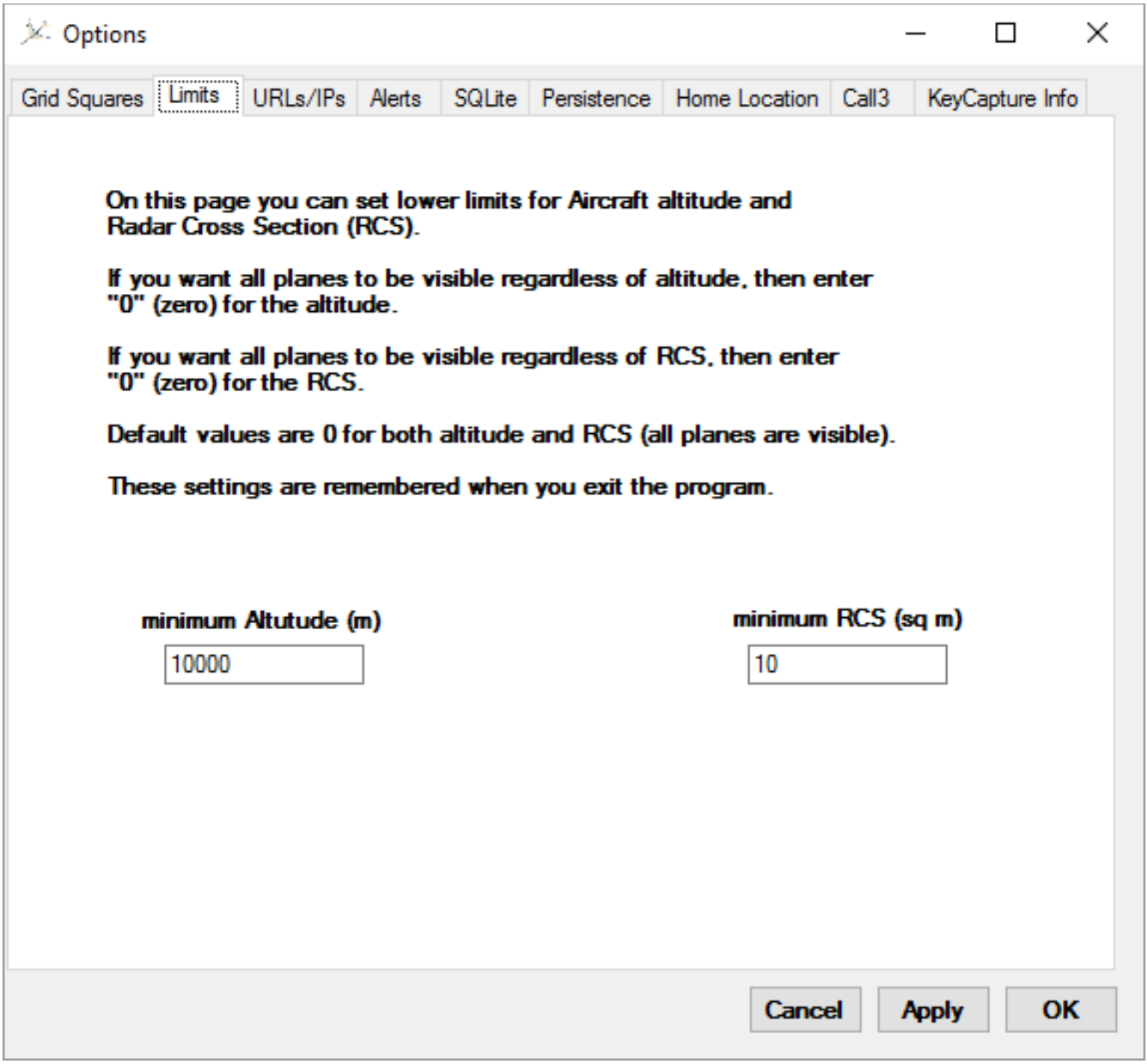


If you don't have the SRTM3 files mentioned on pages 9 and 27 above, then you will get Message Boxes with errors of the sort "SRTM3 File N3xxWyyy required for this path is missing for BW3". To prevent such error messages from appearing, either uncheck the box on this page that is labeled "Missing SRTM File Warning" or download the SRTM3 files as described on pages

You can choose to turn off pop-up grid labels, and you can choose to make the mouse-over icon in the middle of each grid visible or invisible.

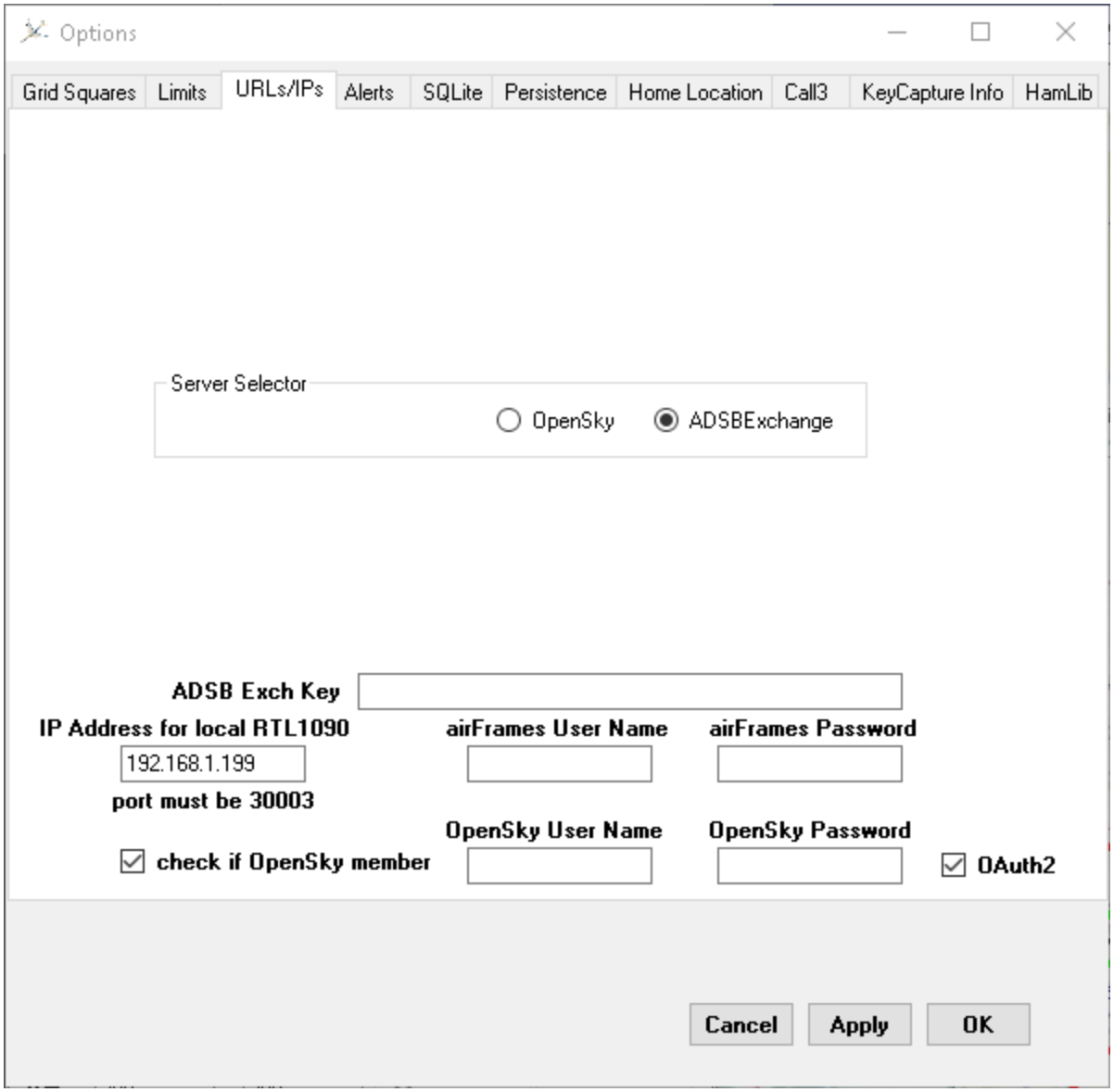
By default, maps for the aircraft display are obtained from an internet map server. If you wish to save maps to your hard drive so that they will be available to this program if you are operating without internet access, then click the "Server and Cache" button while connected to the internet and maps you view will be saved to your hard drive and available to this program when internet access is not available, as long as the "Server and Cache" radio button is

checked. The map cache resides at
../Users/your_user_name/AppData/Local/Gmap.NET/TileDBv5/en/Data.gmdb



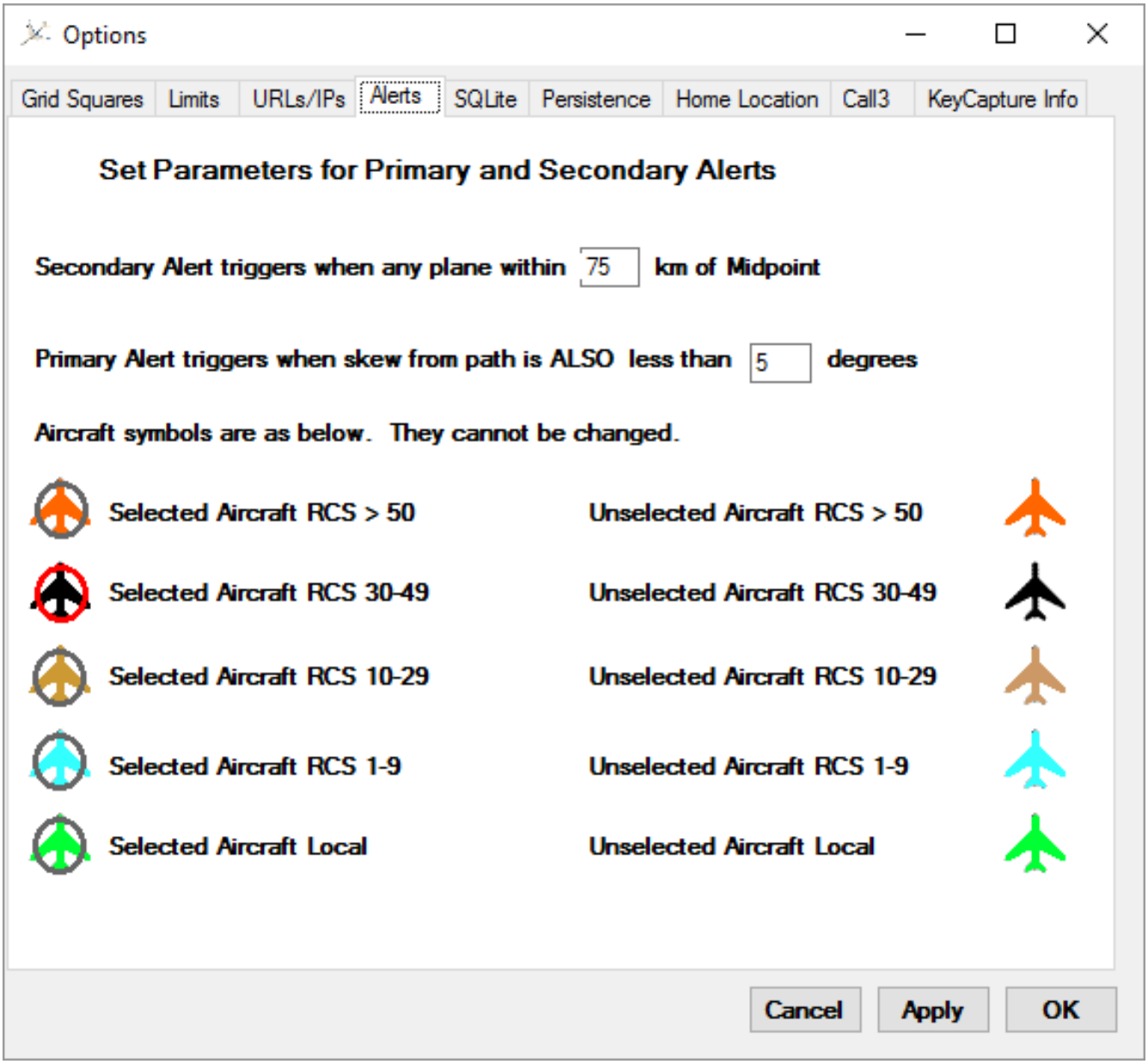
This page is used to set the minimum altitude (in meters) and minimum RCS (in sq. meters). Alternatively, these values can be set using Alt-A for altitude and Alt-R for RCS. Aircraft with values for these parameters below these limits will not be displayed. Once set, these values are remembered from session to session.

As with all AircraftScatterSharp functions that make use of the Alt key or the Control key, the Key Capture button must be enabled for Alt-A and Alt-R to function for this purpose.

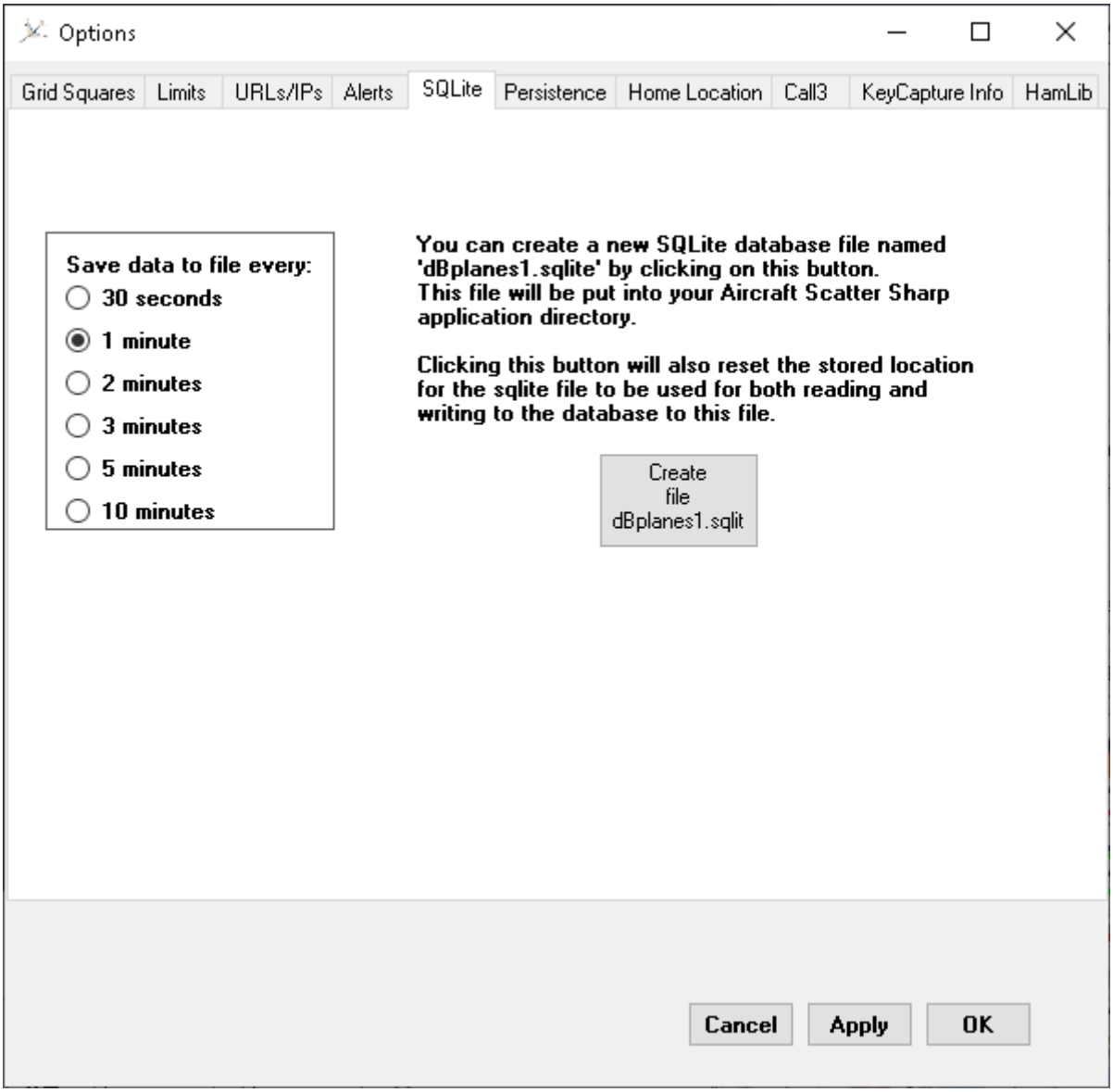


If you are using a local RTL1090 as a plane server, place its IP address here. Its port must be 30003. See section 6 above for information on using ADSB Exchange, airFrames, and OpenSky.

To use <Ctl>F7 to get aircraft information,you need to register with a user name and password at http://www.airframes.org/signup and enter your airFrames.org user name and password on this form. Once you have entered this data it will be remembered by AircraftScatter# and you never need to re-enter it unless your airFrames.org account expires due to 45 days or more of non-use. The first time you type <Ctl>F7 you will be logged onto airFrames.org and when you subsequently select new planes and then type <Ctl>F7 you will be presented with the aircraft data for the aircraft that you have selected.

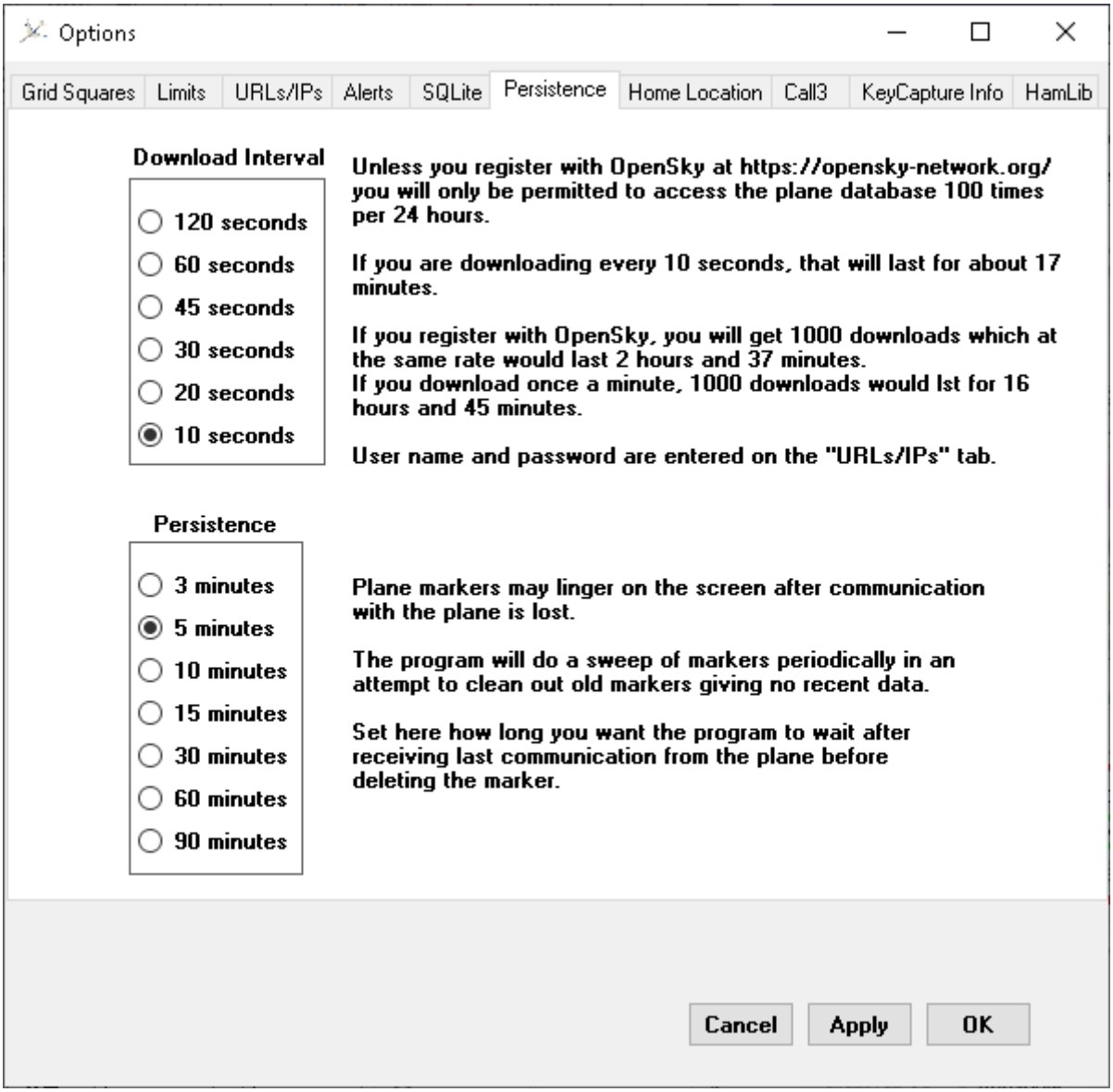


I have found that values of 75 km for the Secondary Alert circle and 5 degrees for the Primary Alert skew angle trigger work well for alerting me as to when aircraft are in a position to give a high likelihood of successful aircraft scatter contacts.



For general database collection I have found that adding data to the database every 3 minutes works well. When I want to collect data for analysis of Doppler rates of change or to closely track and record plane parameters, I collect data every 30 seconds.

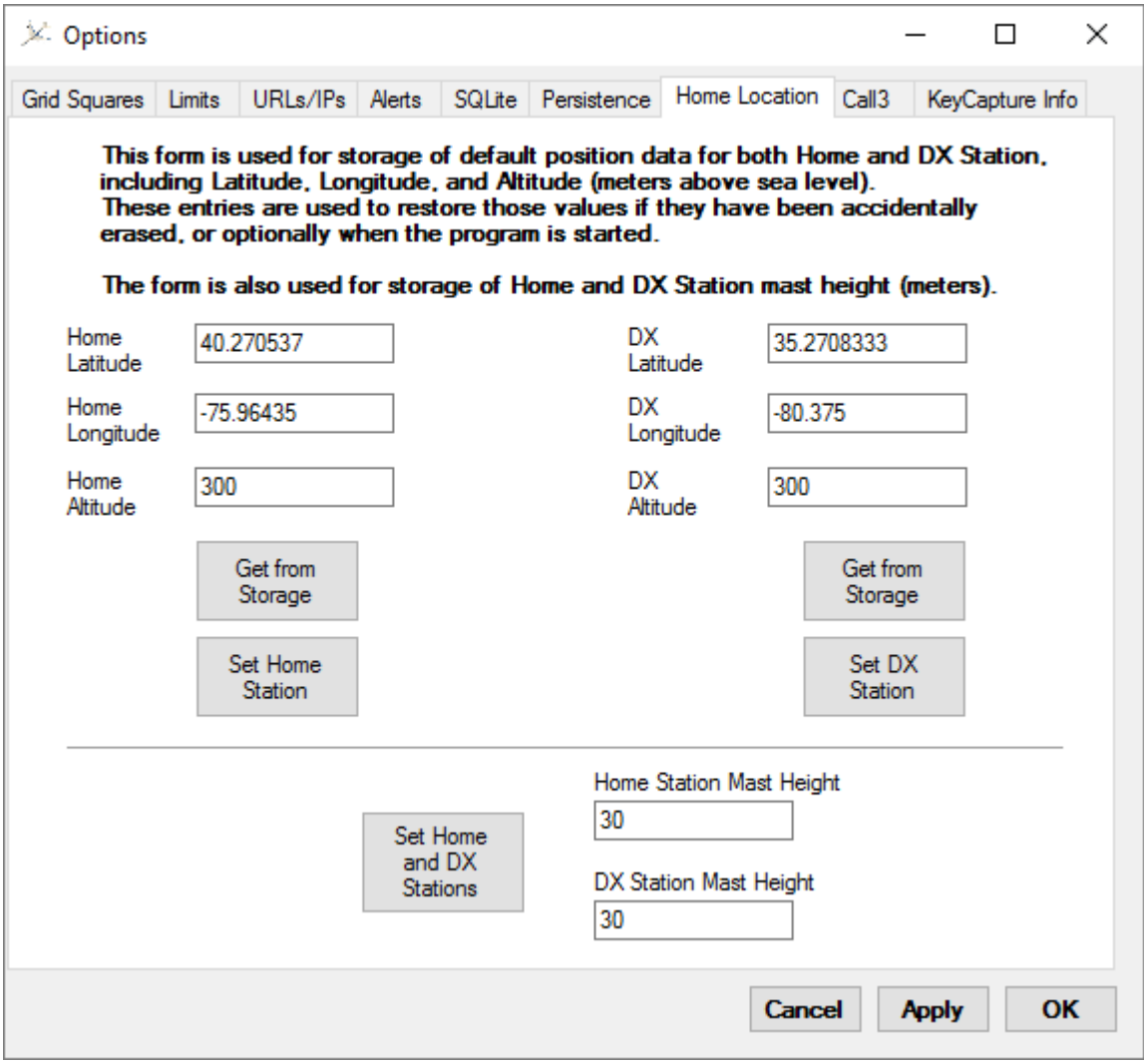
I have never needed to create a new SQLite file after one has been created automatically during program installation, but the capability to create a new one is available on this tab by clicking the "Create file dBplanes1.sqlit" button. Be careful and back up your old file before creating a new one! The dBplanes.sqlite file is typically found in the directory ../Users/your_user_name/AppData/Local/W3SZ.



The persistence tab allows you to set the download interval and also how long a plane will persist on the display after its data is last downloaded. Frequent aircraft position updates are nice, but unless you are an OpenSky registered user you will quickly run out of downloads if you have the download interval set to 10 seconds. On the other hand, if you are a contributing OpenSky user (one who sends them regular aircraft data uploads), you can afford to set a shorter download interval without using up your API download allotment.

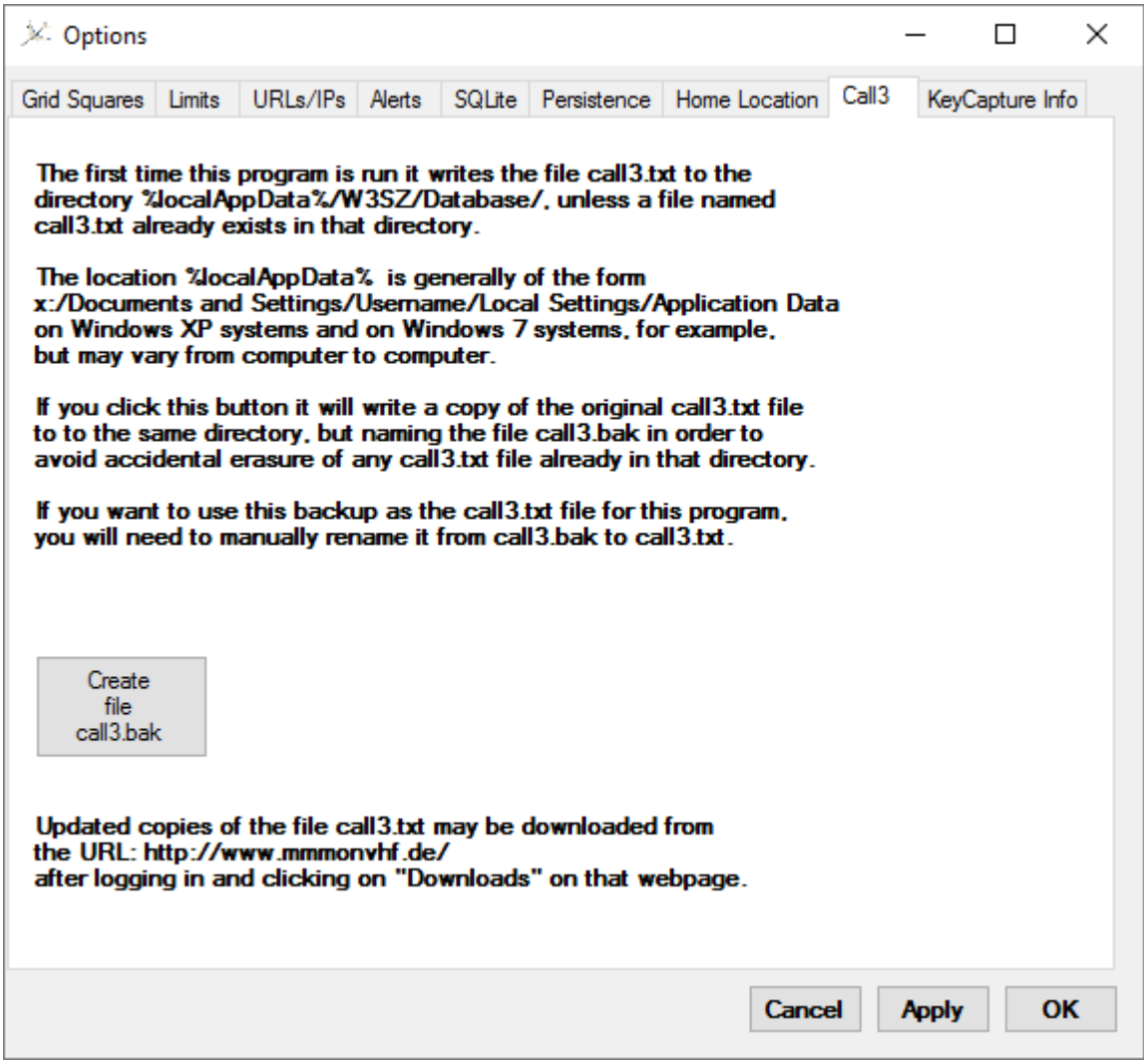
Airplane servers typically contain a number of “dead” planes that are in the database download but no longer sending any new data. Additionally, planes that were initially sending data may move out of range of the plane feeders and stop sending new data. The persistence setting determines how long after the last received message such planes will be scrubbed from the plane display.

I have found that a setting of 10 minutes for this parameter works well for me.



This page allows you to save (if you click "Set Home Station" or "Set DX Station") default locations and altitude for the Home Station and the DX Station, or to retrieve such data if you click "Get from Storage" for either the Home Station or the DX Station. If [1] values are entered here and saved, and if [2] the "Default Home" or "Default DX" check box in the "Station and Aircraft Position Data Area" of the main form are checked and [3] the "Lat" radio button is checked for the Home or DX Station or both, then this data will be used to populate the latitude and longitude for the respective station(s).

At the bottom of this page you can set the default mast height for the Home and the DX stations by clicking the "Set Home and DX Stations" button. This data will then be used to populate the Home and DX Station "Alt" (altitude) text boxes in the "Station and Aircraft Position Data Area" of the main form by adding it to the altitude for that location.

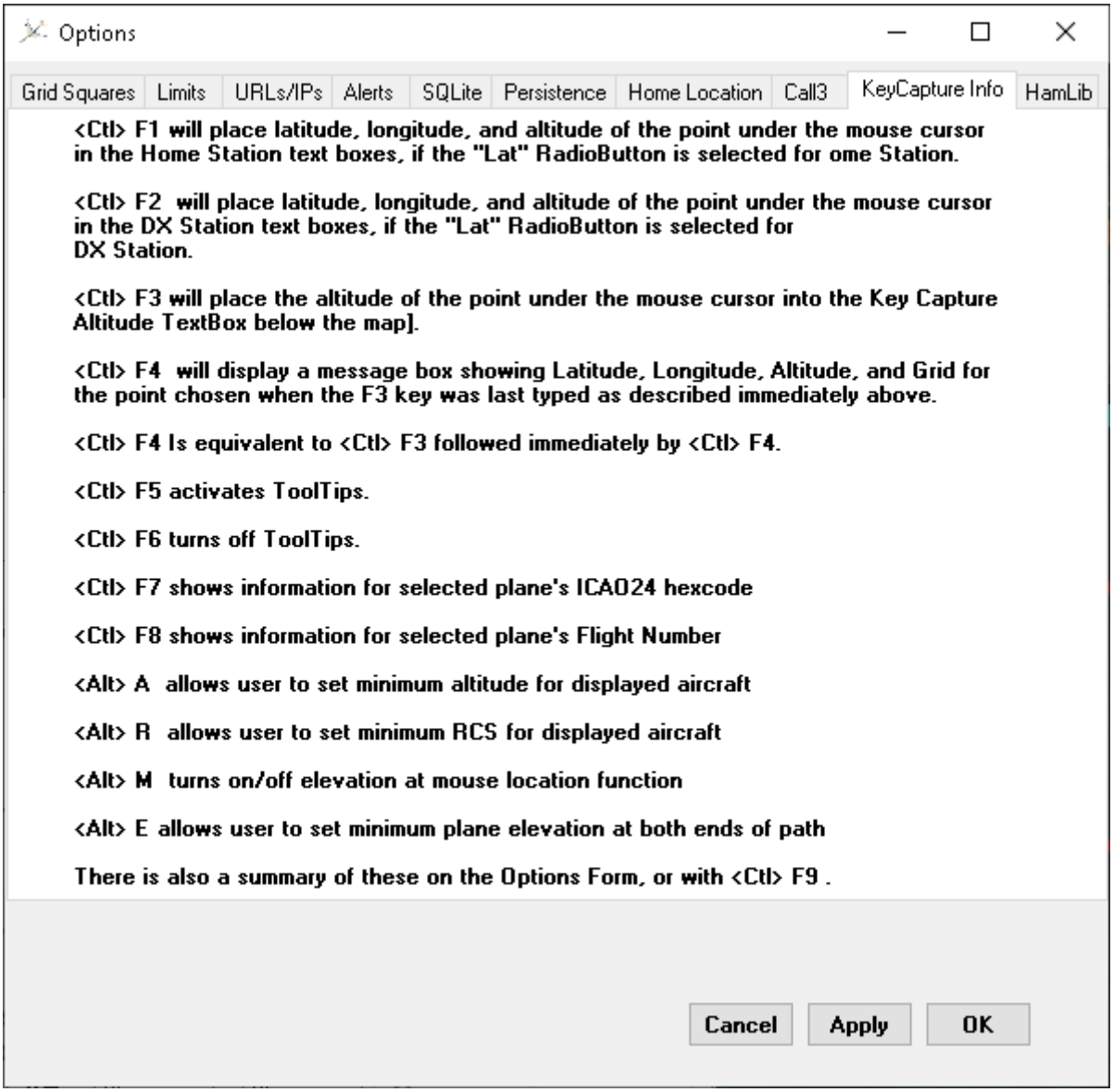


Optionally, a call3.txt file can be used to obtain grid information and thus latitude and longitude for the Home and DX stations. A copy of a call3.txt file is included with this program download but the user is advised to download an updated version when installing this program.

One location from which the call3.txt file can be downloaded is http://www.mmmonvhf.de/download.php

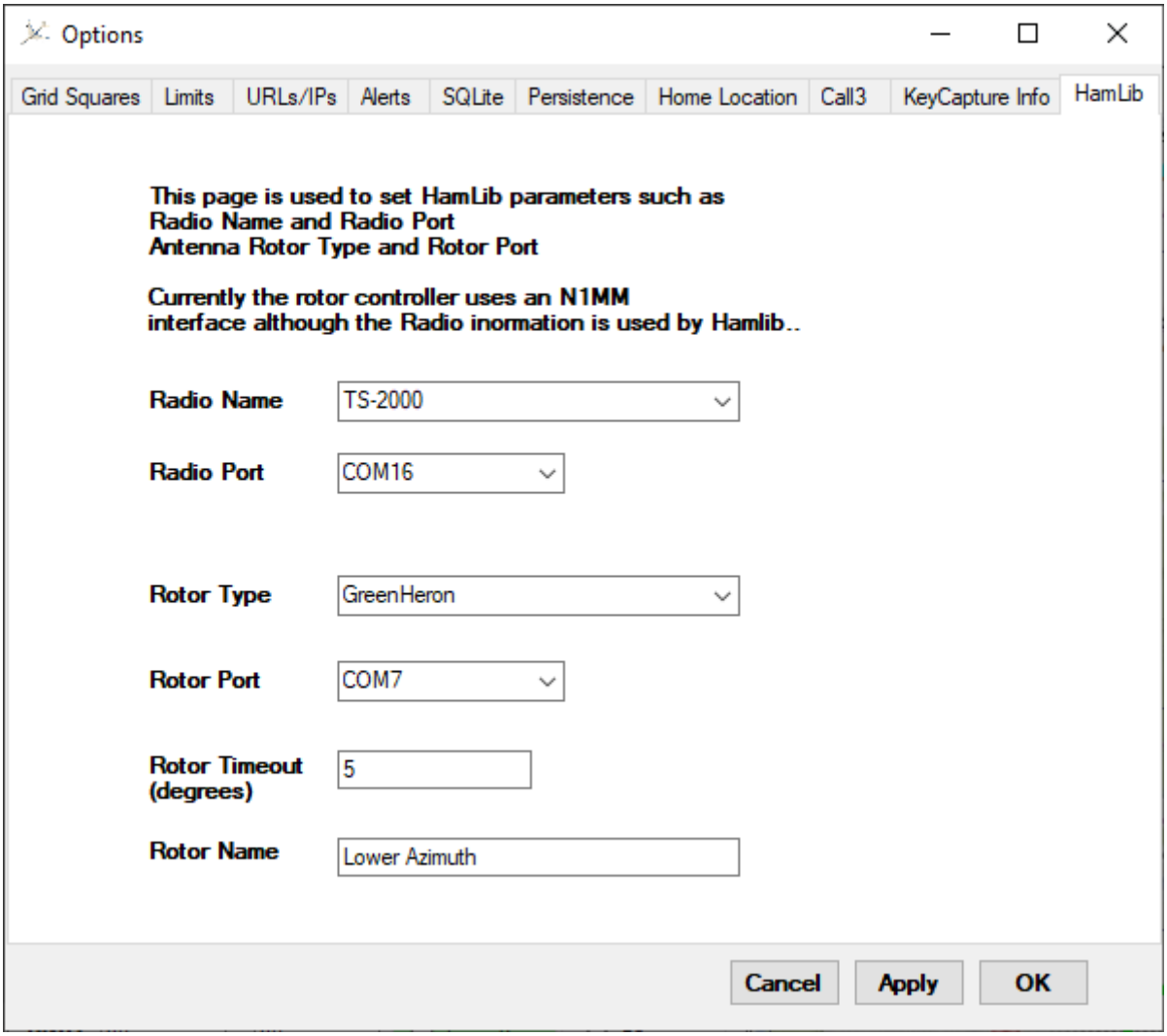
You need to be registered and logged in to that site to download the call3.txt file which is updated daily at this location.

On modern versions of Windows, in order for AircraftScatter# to use this file, it should typically be located at ../Users/your_user_name/AppData/Local/W3SZ/Database.



Key Capture will not function unless you have activated it by clicking the “Key Capture” button, which will have a red background when the key capture function is active.

In addition to the Function-Key related items, <Alt> A, <Alt>E, and <Alt> R will set the minimum display altitude, elevation, and RCS when key capture is activated, and <Alt> M will turn on and off the display in the Key Capture Altitude text box of the elevation of the map point under the mouse cursor.



The final tab is for setting up radio and rotor control.

Antenna control is obtained via the N1MM Rotor Control application, and one needs to set the rotor type, rotor port, and rotor name so that they are identical to the settings in the N1MM Rotor Control application. Plane tracking is not useful in making QSOs but I use this function in some of the experimental work that I am doing.

The rotor timeout can be set to be any number of degrees greater than 0.1.

Plane tracking is in general not sufficiently predicable for useful Doppler control. This feature, which uses HamLib, is not supported. If you use it you are on your own.

References

1 Rehr R,Tropospheric Scatter (Troposcatter) Propagation for VHF, UHF, and Microwave Frequencies. Mid-Atlantic States VHF Conference 2014. Also https://w3sz,com/NEW_W3SZ_AircraftScatterPaper2023.pdf

2 Kozma W, ITM-Longley-Rice https://github.com/NTIA/itm-longley-rice

3 Longley AD and Rice PL, Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain: A Computer Method – 1968. NTIA Technical Report ERL 79-ITS 67, July 1968.

4 Flowers, A. RainScatter 1.61. http://www.frontiernet.net/~aflowers/rainscatter/

5 Jet Propulsion Laboratory, California Institute of Technology. https://science.jpl.nasa.gov/projects/srtm/

6 SRTM3 files for North America can be downloaded from https://srtm.kurviger.de/SRTM3/index.html