EITRay

Version 3.0

User Guide

一、General function introduction

The Gaussian Beam Tracing (GBT) algorithm used by this software is a commonly employed method for acoustic field calculation. It can simulate the propagation and reflection of sound waves in complex environments. The fundamental idea of this algorithm is to treat the sound wave as being composed of many rays, and then to calculate the propagation and reflection of the sound wave in the air by using the propagation laws of these rays. The advantage of the GBT algorithm is that it can quickly compute the propagation and reflection of sound waves in complex environments with relatively high accuracy in the results.

The software's input consists of four parts: calculation type, number and positions of sources, atmospheric conditions, and environmental geometry files. The calculation type refers to the type of acoustic field calculation, which can be indoor or outdoor, single-frequency or multi-frequency, and so on. The number and positions of the sources refer to the quantity and location information of the sound sources, which have a significant impact on the results of the acoustic field calculation.

The atmospheric conditions include air temperature, relative humidity, and pressure — parameters that affect the speed of sound propagation and attenuation in the atmosphere. The environmental geometry files include the geometric information of objects such as buildings, terrain, roads, water, and trees, and are provided in STL format. This information can be used to simulate the propagation and reflection of sound waves in different environments, thereby obtaining the distribution of the acoustic field.

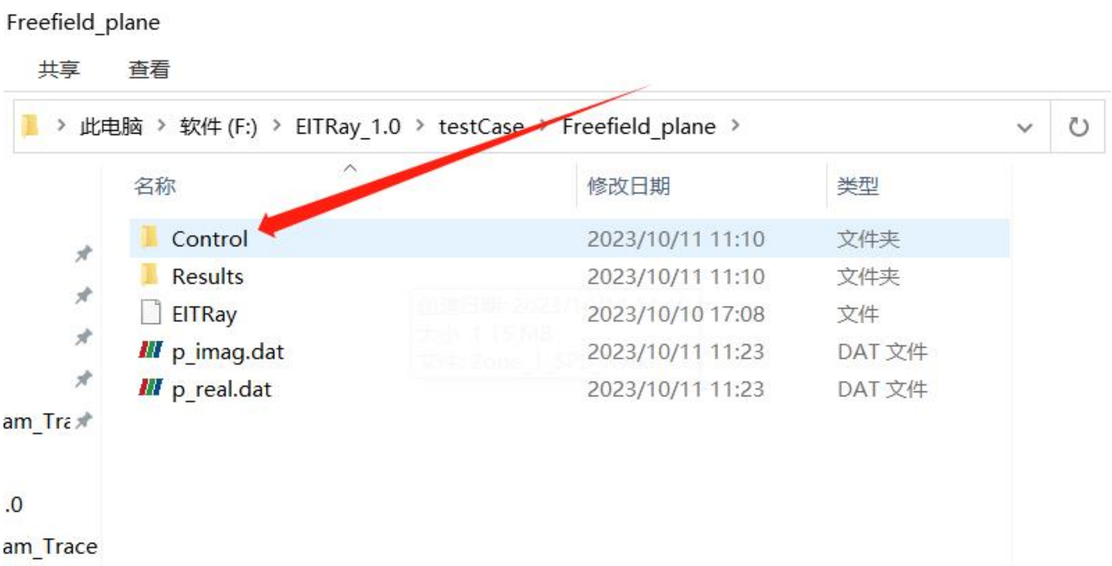
In addition to the aforementioned input information, the software also requires several ray-tracing related parameters, such as the dimensionality, azimuth, total number of rays, and whether the rays are compressed. These parameters affect both the accuracy of the acoustic field calculation and the computation time. The dimensionality refers to whether the acoustic field calculation is two-dimensional or three-dimensional; the azimuth indicates the direction of the sound source; the total number of rays refers to the number of rays used in the calculation; and whether the rays are compressed indicates if the rays are compressed during the calculation process to improve computational efficiency.

Ultimately, the software can output a 3D-renderable and visualizable VTK file, which can be used to display the acoustic field visually. The VTK file is a commonly used format for 3D visualization and can be opened and edited in many software programs. By visually displaying the acoustic field, users can gain a more intuitive understanding of the distribution of the field and the propagation and reflection patterns of sound waves in different environments, thus facilitating better acoustic design and optimization.

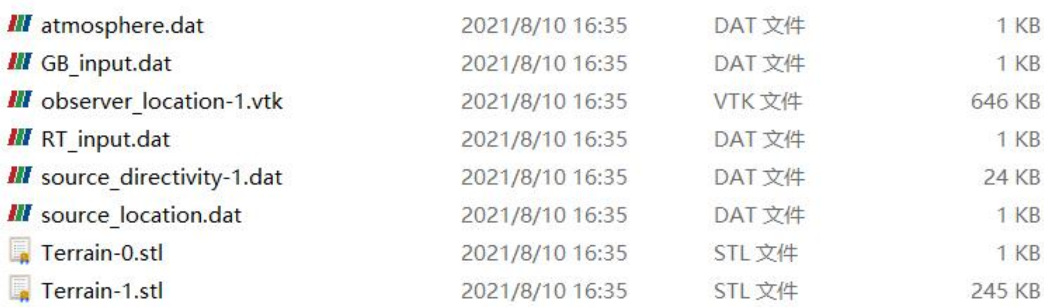
2 introduction

2.1 input

The input files for this program are saved in the folder Control:



When you open it, you will see the following kinds of files:



2.2.1 atmosphere.dat

Atmospheric conditions file where atmospheric conditions are specified, including air temperature (C), relative humidity (%), and pressure (atm). Atmospheric attenuation is calculated based on the atmospheric conditions.

atmosphere.dat - 记事本

文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

```
20  ! air temperature(C)
70  ! Ralative humidity(%)
1   ! pressure(atm)
```

2.2.2 GB_input.dat

Input file for the Gaussian beam in which the number of source frequencies and a list of frequencies to be tested are to be written. If the number of source frequencies is greater than 1, the code will run a broadband simulation. For the broadband case, the output is the total SPL with uncorrelated summation.The observer format has two options:

VTK, TEC, i.e., .vtk file and .dat file. And the format of the observer file and the output SPL file should remain the same. The number of output observation regions is equal to the number of observer location input files.

VTK format should include input files in Control folder if there are 3 observation regions:

Observer_location-1.vtk、observer_location-2.vtk、observer_location-3.vtk

One of the beam parameters, is a constant that controls the beam width and the curvature evolution along the center ray. Adaptive beam parameters are applied independent of this input number. To use the manually defined beam parameters, the source code in GBvars.cpp should be modified. Only a negative constant can generate a finite width beam. In general, a beam constant with a large amplitude will give a relatively wide beam near the source region, but increasing slowly along the direction of propagation. A small magnitude will start with a narrower beam, but the increase will be very wide, which can lead to large deviations over long propagation distances.

The following chart shows common values for different reflective surfaces:

Description of surface	Flow resistivity cgs rayls (1 cgs rayls = 1000 Pa s/m^2)
Dry snow, new fallen 0.1 m over about 0.4-m older snow	10–30
Sugar snow	25–50
In forest, pine, or hemlock (Ref. 22)	20–80
Grass: rough pasture, airport, public buildings, etc.	150–300
Roadside dirt, ill-defined, small rocks up to 0.1-m mesh	300–800
Sandy silt, hard packed by vehicles	800–2500
"Clean" limestone chips, thick layer (0.01- to 0.025-m mesh)	1500–4000
Old dirt roadway, fine stones (0.05-m mesh) interstices filled	2000–4000
Earth, exposed and rain-packed	4000–8000
Quarry dust, fine, very hard-packed by vehicles	5000–20 000
Asphalt, sealed by dust and light use	~30 000
Upper limit set by thermal-conduction and viscous boundary layer	2×10^5 to 1×10^6

Specific internal documentation details are shown below:

GB_input.dat - 记事本

文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

```
1                              !number of source freq.
100
VTK                       !observer file format
VTK                       !output SPL file format
1                         !number of observer zones for output
-45874             !IMAG component of beam parameter
=======================================================
 Flow reactance of different zones (<0 == hard wall)
=======================================================
 Building    Terr     Road      Water      Tree
 -10         -10      -10       -10        -10
1650         1650     1650      0          0
1500         1500     1500      0          0
```

The first two rows are the number of sound sources and the source frequency.

And in the last three rows, the first row is the flow impedance, the second row is the sound velocity value, and the third row is the density.。

2.2.3 observer_location-x.vtk/.dat

The observer position file contains information about point coordinates and triangle elements. For the VTK format, the Ascii type generated by Praview should be used. For DAT format, the number of observers and their coordinates are provided first, followed by the number of triangles and vertex indexes. The details are shown below:

observer_location-1.vtk - 记事本

文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

```
# vtk DataFile Version 4.0
vtk output
ASCII
DATASET POLYDATA
POINTS 10201 float
0 0 3 0 0.5 3 0 1 3
0 1.5 3 0 2 3 0 2.5 3
0 3 3 0 3.5 3 0 4 3
0 4.5 3 0 5 3 0 5.5 3
0 6 3 0 6.5 3 0 7 3
0 7.5 3 0 8 3 0 8.5 3
```

```
50 44 3 50 44.5 3 50 45 3
50 45.5 3 50 46 3 50 46.5 3
50 47 3 50 47.5 3 50 48 3
50 48.5 3 50 49 3 50 49.5 3
50 50 3
POLYGONS 20000 80000
3 0 1 101
3 102 101 1
3 1 2 102
3 103 102 2
3 2 3 103
3 104 103 3
3 3 4 104
3 105 104 4
3 4 5 105
3 106 105 5
3 5 6 106
3 107 106 6
3 6 7 107
3 108 107 7
```

```
3 10200 10199 10099

POINT_DATA 10201
NORMALS Normals float
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
0 0 -1 0 0 -1 0 0 -1
```

```
0 0 -1
TEXTURE_COORDINATES TextureCoordinates 2 float
0 0 0.01 0 0.02 0 0.03 0 0.04
0 0.05 0 0.06 0 0.07 0 0.08 0
0.09 0 0.1 0 0.11 0 0.12 0 0.13
0 0.14 0 0.15 0 0.16 0 0.17 0
0.18 0 0.19 0 0.2 0 0.21 0 0.22
0 0.23 0 0.24 0 0.25 0 0.26 0
0.27 0 0.28 0 0.29 0 0.3 0 0.31
0 0.32 0 0.33 0 0.34 0 0.35 0
0.36 0 0.37 0 0.38 0 0.39 0 0.4
0 0.41 0 0.42 0 0.43 0 0.44 0
0.45 0 0.46 0 0.47 0 0.48 0 0.49
0 0.5 0 0.51 0 0.52 0 0.53 0
0.54 0 0.55 0 0.56 0 0.57 0 0.58
0 0.59 0 0.6 0 0.61 0 0.62 0
0.63 0 0.64 0 0.65 0 0.66 0 0.67
0 0.68 0 0.69 0 0.7 0 0.71 0
0.72 0 0.73 0 0.74 0 0.75 0 0.76
0 0.77 0 0.78 0 0.79 0 0.8 0
0.81 0 0.82 0 0.83 0 0.84 0 0.85
0 0.86 0 0.87 0 0.88 0 0.89 0
0.9 0 0.91 0 0.92 0 0.93 0 0.94
0 0.95 0 0.96 0 0.97 0 0.98 0
0.99 0 1 0 0 0.01 0.01 0.01 0.02
0.01 0.03 0.01 0.04 0.01 0.05 0.01 0.06 0.01
0.07 0.01 0.08 0.01 0.09 0.01 0.1 0.01 0.11
0.01 0.12 0.01 0.13 0.01 0.14 0.01 0.15 0.01
0.16 0.01 0.17 0.01 0.18 0.01 0.19 0.01 0.2
0.01 0.21 0.01 0.22 0.01 0.23 0.01 0.24 0.01
0.25 0.01 0.26 0.01 0.27 0.01 0.28 0.01 0.29
0.01 0.3 0.01 0.31 0.01 0.32 0.01 0.33 0.01
0.34 0.01 0.35 0.01 0.36 0.01 0.37 0.01 0.38
0.01 0.39 0.01 0.4 0.01 0.41 0.01 0.42 0.01
0.43 0.01 0.44 0.01 0.45 0.01 0.46 0.01 0.47
0.01 0.48 0.01 0.49 0.01 0.5 0.01 0.51 0.01
```

2.2.4 RT_input.dat

```
'3D'                     !run type 3D/2D
100   0    180              !nTheta, theta min, theta max (0<theta<180)
100   0    360             !nPhi,     phi min,   phi max (0< phi <360)
0.0001                      !time step [s]
5000                      !number of time steps
20                       !maximum number of reflections
!======================================================
0                                    !output auto-divided split zone domain? (1
0                                    !output RAY VTK file? (1=YES, 0=NO)
0  10                   !Particle tracking (1=ON, 0=OFF), Write Every
2                            !Mode [1=RT+SaveRT], [2=RT+GB], [3=LoadRT+GB]
1                      !compression flag [1=compress] [other num=No compress]
1E-5                             !Ray compression. Smaller -> less compression
```

The ray tracing input file, with the first line being the run type parameter specifies ray emission in the vertical plane (2D) or in full 3D space. The initial ray emission direction is defined by the fine fraction of elevation (theta) and azimuth (phi) directions and the corresponding angular range. The total number of rays is the product of ntheta and nphi. The angular range in both directions should contain the angular range defined in the source file. Each ray tracing time step is uniform. The ray tracing process will end when the total number of rays or the number of reflections exceeds the limits defined in this file. For ray file output, the flag should be 1. For the ray compression option, 1 indicates that a compression technique is used. The following ray compression parameters set the threshold for ray compression, i.e. the change in direction between two neighboring ray tracing steps. A smaller ray compression threshold will result will result in a smaller ray compression.

2.2.5 source_location.dat

```
'A'
1
30 30 5
```

The source location file defines the calculation type, the number of sources and their respective locations.

For the first line the calculation type, if it is 'M', the code will output the result for each source location, and if the calculation type is 'A', it will output the overall result, which includes the sum of the contributions of all the sources.

The second line is the number of sources, while the third line is the coordinates at which the sources are located.

2.2.6 source_directivity-x.dat/source_directivity-n_m.dat

For a single source, the filename for the detailed settings should be source_directivity-x.dat, while for multiple sources, the filename should be named source_directivity-n_m.dat, where n is the number of sources and m is the number of frequency components.

```
*source_directivity-1.dat - 记事本
文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)
 31   !nTheta
 0.00000  0.10472  0.20944  0.31416  0.41888  0.52360  0.62832
  61    !nPhi
 0.00000  0.10472  0.20944  0.31416  0.41888  0.52360  0.62832
  !directivity
1        1        1        1        1        1        1
1        1        1        1        1        1        1
1        1        1        1        1        1        1
1        1        1        1        1        1        1
  !phase
 0.00000  0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
 0.00000  0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
 0.00000  0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
 0.00000  0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
 0.00000  0.00000  0.00000  0.00000  0.00000  0.00000  0.00000
```

The number of elevation angles (theta), the number of azimuthal angles (phi) and their respective angular values in radians are defined in the first four lines. In what follows the amplitudes and phases of the corresponding tables of pressure fields on the radius sphere are listed.

2.2.7 Building.stl、Terrain.stl、Road.stl、Water.stl、Tree.stl

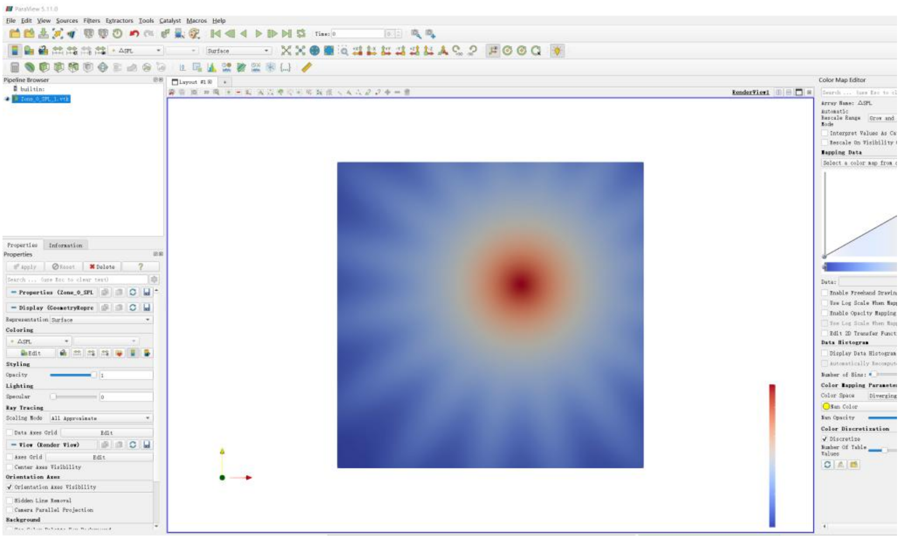
The environment geometry file is read into the code as a reflected obstacle. A binary STL file should be used. The user should rename the geometry file to the file name selected in the list above. If a file with the above name cannot be found, a free-field simulation will be performed.

2.3 Output

Eventually the program outputs a VTK\TEC file containing SPL information, which is specified as: zone_m_SPL_n.vtk/.dat, whose format corresponds to the input observer file, and where m and n are two integers distinguishing between different observer location regions and different source locations, respectively.

Zone_0_SPL_1.dat	2023/10/9 10:42	DAT 文件	832 KB
Zone_0_SPL_1.vtk	2023/9/22 17:34	VTK 文件	553 KB

The file is recommended to be opened with Paraview software, which opens the page as follows:



2.4 Description of terms

The distance in the program is in meters and the time is in seconds. The output of the program is the sound pressure level.

2. acoustic ray tracing theory (ignored)

3.Basic Arithmetic Examples

In this section, three scenarios, a planar field, an indoor sound field, and an outdoor sound field, will be used to show how to run the program and how to use Paraview to process the obtained SPL results.

3.1 Free Fields

3.1.1 Introduction

A planar sound field is a scenario in which a sound wave propagates in a particular direction and all relevant parameters of the wave (e.g., sound pressure, sound velocity) remain constant in a plane perpendicular to that direction.

3.1.2 Input File Settings

(1) For the file RT_input.dat：

```
'3D'                                   !run type 3D/2D
100    0    180                        !nTheta, theta min, theta max (0<theta<180)
100    0    360                        !nPhi,    phi min,   phi max (0< phi <360)
0.0001                                 !time step [s]
5000                                   !number of time steps
20                                     !maximum number of reflections
!==============================================================================!
0                   !output auto-divided split zone domain? (1=YES, 0=NO)
0                   !output RAY VTK file? (1=YES, 0=NO)
0   10                                 !Particle tracking (1=ON, 0=OFF), Write Every
2                            !Mode [1=RT+SaveRT], [2=RT+GB], [3=LoadRT+GB]
1                                      !compression flag [1=compress] [other num=No compress]
1E-5                    !Ray compression. Smaller -> less compression but more accurate.
```

（2）GB_input.dat:

```
1              !number of source freq.
100            ! source freq.
VTK                !observer file format
VTK                    !output SPL file format
1                  !number of observer zones for output
-45874                 !IMAG component of beam parameter
==========================================================
 Flow reactance of different zones (<0 == hard wall)
==========================================================
 Building     Terr       Road        Water       Tree
 -10          -10        -10         -10         -10
1650          1650       1650        0           0
1500          1500       1500        0           0
```

（2）source_location.dat:

'A'

1

30 30 5

（3）source_directivity-1.dat:

31 !nTheta

0.00000 0.10472 0.20944 0.31416 0.41888 0.52360 0.62832

0.73304 0.83776 0.94248 1.04720 1.15192 1.25664 1.36136 1.46608

1.57080 1.67552 1.78024 1.88496 1.98968 2.09440 2.19911 2.30383

2.40855 2.51327 2.61799 2.72271 2.82743 2.93215 3.03687 3.14159

61 !nPhi

0.00000 0.10472 0.20944 0.31416 0.41888 0.52360 0.62832

0.73304 0.83776 0.94248 1.04720 1.15192 1.25664 1.36136 1.46608

1.57080 1.67552 1.78024 1.88496 1.98968 2.09440 2.19911 2.30383

2.40855 2.51327 2.61799 2.72271 2.82743 2.93215 3.03687 3.14159

3.24631 3.35103 3.45575 3.56047 3.66519 3.76991 3.87463 3.97935

4.08407 4.18879 4.29351 4.39823 4.50295 4.60767 4.71239 4.81711

4.92183 5.02655 5.13127 5.23599 5.34071 5.44543 5.55015 5.65487

5.75959 5.86431 5.96903 6.07375 6.17847 6.28319

!directivity

1 1 1 ...

!phase

0.00000 0.00000 0.00000 ...

（4）observer_location-1.vtk:

You need to go to export it in the STL file by paraview itself, the plane field reference example file Freefield_plane/Control/observer_location-1.vtk.

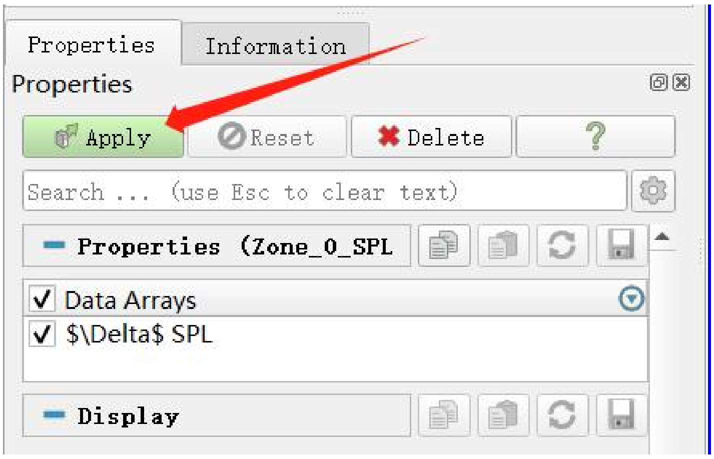
（5）STL:

There is no need for a setup in a flat field.

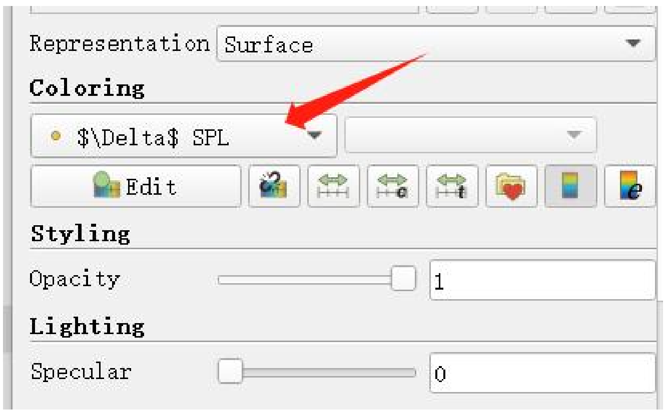
3.1.3 output

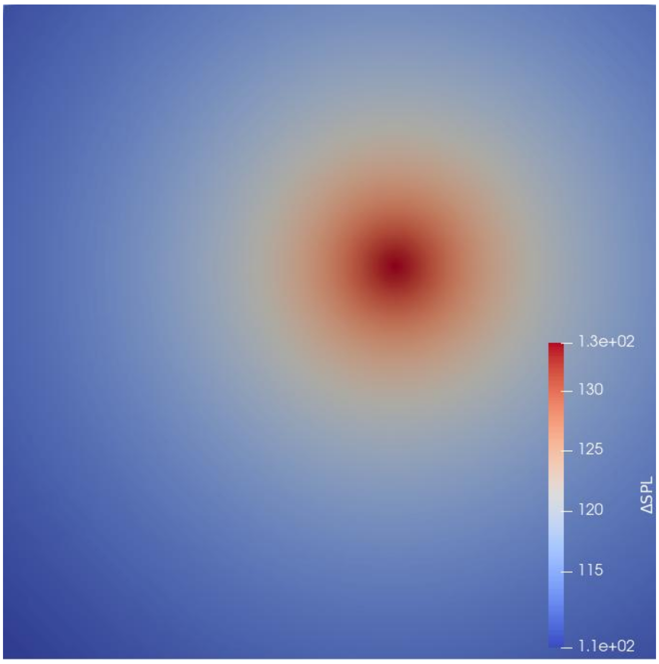
When the program has finished its calculations, it will see a file:

After opening it with Paraview:



Color display selection:





Above is the planar sound field generated by this program.

3.2 Indoor Sound Field Calculations

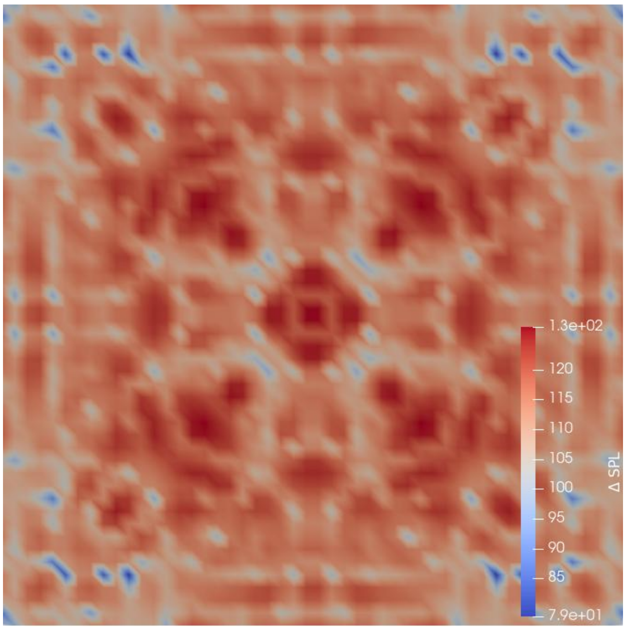
3.2.1 Introduction

An indoor sound field is an acoustic environment within a finite enclosed space (e.g., a room, hall, or theater) in which sound waves interact with the boundaries of the space (walls, ceilings, and floors) and with objects within it.

3.2.2 Input file settings

In the source_location.dat file, change the location of the sound source of the flat field to (0, 0, 0), then add a room element building.stl, and generate a new observation point file through paraview. Control.

3.2.3 output



Above is the indoor sound field generated by this program.

3.3 Outdoor Sound Field Calculations

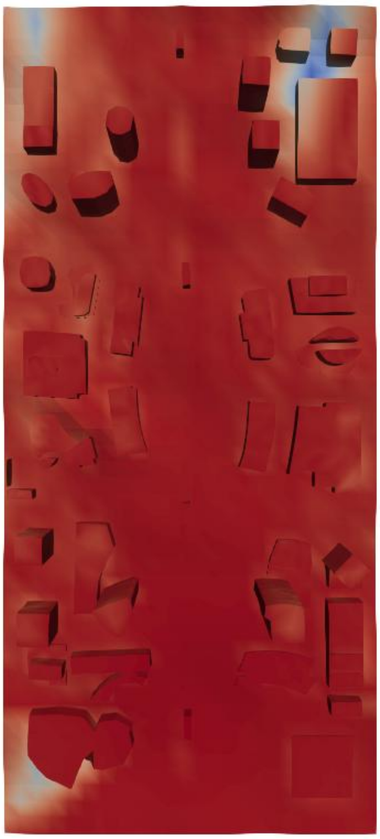
3.3.1 Introduction

An outdoor sound field is an acoustic environment in an open space, not limited by enclosed structures. It designs the interaction of sound waves with objects and media such as terrain, buildings, vegetation, lakes, etc.

3.3.2 Input File Settings

The specific example input file is in Guangzhou_case/Control.

3.3.3 Output



Above is the outdoor sound field generated by this program.