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Introduction to GLOSI - The Global and Local One-dimensional Solution for ICRF Heating

This document describes the background and use of the GLOSI plasma modeling code.

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INTRODUCTION

GLOSI, the Global and Local One-dimensional Solution for ICRF Heating, is a FORTRAN code designed to solve 1D wave equations resulting from RF heating of plasmas. The code is important in that its numerical stability allows it to be used both locally and globally. A finite difference method is employed to solve the differential equations for three types of boundary conditions. Wave scattering boundary conditions allow for a good local solution. Antenna wave excitation boundary conditions are used to solve for fast and slow waves in plasmas. However, the main use for GLOSI is to calculate impedance matrices and describe plasma/antenna coupling, which can be used to calculate antenna loading. This is done using the tangential wave magnetic field boundary conditions. Additionally, the code includes plasma thermal effects and calculates collisionless power-absorption and kinetic energy flux. When paired with RANT3D, GLOSI becomes a useful tool for analyzing RF antennas, both in design work and in experimental predictions and analysis. Contact Mark Carter (cartermd@ornl.gov) for questions about GLOSI.

THE SLAB MODEL

The model used by GLOSI is a slab model of the plasma. Basically, the plasma is opened toroidally and then opened poloidally so that the entire edge of the plasma is facing one direction and the center of the plasma is facing another. The plasma is then described in Fourier space, in terms of modes. Hopefully this will explain somewhat how the model is derived; however, picturing something like this is challenging.

INPUTS

GLOSI uses two files as input. The first, *glosi.in* is a simple text file that defines several switches and values used by the code. These include boundary conditions, tokamak size and shape, plasma characteristics, and resolution. The second file, *menard* is an optional input file that provides real plasma information such as density and magnetic fields.

GLOSI.IN

The *glosi.in* file has numerous parameters. Below is a listing of these parameters and a brief description of them.

impedance - This is a switch that determines what calculations the code performs. A value of 0 tells the code to perform all calculations, while a value of 1 results in only the impedance calculation. The impedance calculation is what is necessary to use RANT3D.

ipvm - This selects whether GLOSI is run on networked computers. 0 corresponds to off; 1 corresponds to on. The value for this parameter will most likely be 0 (single processor).

nproc - This is the number of processes created when *ipvm* = 1.

isigma - This number determines the dielectric tensor type. A Fukuyama tensor is determined by the value 1, a Brambilla tensor by 2.

ileft - This switch determines the boundary conditions to the left. Scattering boundary conditions have a value of 1. Cunducting wall and antenna conditions have a value of 2, and scattering boundary conditions for IBW and SAW with total Fast Wave reflection is represented by 12.

iright - This parameter determines right-side boundary conditions. Again, scattering boundary conditions are 1, with conducting wall and antenna are 2. An interface with an antenna which has a known RF magnetic field is 3.

xant2 - This number is the position, in meters, of the antenna relative to the plasma center. This number is either the same as or similar to the minor radius.

rmaj - This is the major radius in meters.

rmin - This is the minor radius in meters.

xleft - this is the position of the left-hand boundary in meters relative to the plasma center.

xright - This is the position of the right-hand boundary in meters, relative to the plasma center.

aperiod - This value represents <not sure>.

rperiod - This value represents <not sure>.

mstart - This is the poloidal mode number to start on.

mstop - This is the poloidal mode number to stop on. It should be greater than or equal to *mstart*.

nstart - This is the toroidal mode number to start on.

nstop - This is the toroidal mode number to stop on. It should be greater than or equal to *nstart*.

itprof - This parameter determines the temperature profile switch to use. Its values are:

1 - Exponential

2 - Parabolic

3 - Parabolic squared

4 - Flat

5 - Test profile for antenna loading computation

6 - Central and edge density profile

7 - Central and edge density profile with lower limit at edge

8 - Marakami's profile

9 - Gaussian profile

t0s - This is the initial temperature in eV.

tlims - This value is <not sure>

efoldt - This is <not sure>

xefoldt - This is <not sure>

idprof - This switch determines the density profile used. It's valued are described below:

1 - Parabolic

2 - Flat

3 - Test profile

4 - Test profile for antenna loading computation

5 - Central and edge density profile

6 - Central and edge density profile with lower limit at edge

7 - Profiles for Murakami

8,20 - Profiles for the experimental data points. If you have an experimental profile to use in the program, this is the setting to use.

9 - Exponential

10 - Hyperbolic tangent

11 - Hyperbolic tangent with nlim at xright

12 - Clipped hyperbolic tangent using nlim as a clip instead of a minimum

improf - This is the mass profile/collisional effect switch.

1 - No collisional effect

2 - Constant collision profile

3 - Use the collision frequency in Swanson, *Plasma Waves*, 1989, p. 102. This is valid for single-ion plasma only.

4 - Simple electron-neutral collision model

5 - Combined coulomb plus neutral constant for electrons. Uses the collision frequency in Swanson, also valid for single-ion species only.

tolode - This value determines the ODE solver tolerance. Smaller give higher resolutions but with slower computation times. Larger numbers give faster computations but with lower resolution.

ninit - This value sets the initial ODE solver mesh size.

mxgrid - This value is the maximum ODE solver mesh size. If *ninit* equals *mxgrid*, then a non-adaptive mesh is used. If *ninit* does not equal *mxgrid*, then an adaptive mesh is used. However, if *impedance* is defined to be 0, *ninit* must equal *mxgrid*.

frf - This value represents the frequency, in hertz, of the RF antenna.

eta - This value represents a concentration, but can have multiple values. The first value is the electron concentration, and following values are ion concentrations. The electron concentration should be set to 1, and the ion concentrations should add up to be 1.

ms - This value, like *eta*, can have multiple numbers. The numbers correspond to the numbers in *eta* and represent the mass of the species. Electrons would have a mass of 1, hydrogen 1, and deuterium a mass of 2.

qs - This value corresponds to *eta* and *ms*, representing the charge of the species. Electrons have charge -1, while hydrogen and deuterium have charge 1.

ibyprof - This switch determines the poloidal magnetic field as a function of radius.

1 - No poloidal magnetic field

2 - Constant

3 - Same as toroidal magnetic field

4 - Sheared hyperbolic tangent

20 - Experimental data.

ibzprof - This switch determines the toroidal magnetic field as a function of radius.

1 - Tokamak magnetic field

2 - Expansion of tokamak magnetic field

3 - Generalized polynomial

20 - Experimental data

bzsign - This determines the direction of the toroidal magnetic field and can either be -1 or 1.

MENARD

The *menard* file contains experimental data for a set of radial points. The first number in the file indicates the number of points in the file. This number is then followed by sets of four numbers for each point. The first number in each set of four is the radial position. The second number is the plasma density at that point. The third and fourth numbers are the toroidal and poloidal magnetic fields at the point. These numbers are used when *idprof* = 20, *ibyprof* = 20, and *ibzprof* = 20.

RUNNING GLOSI

Once the input files have been properly created, running GLOSI is fairly easy. To run a case, place both of the input files in a directory and then make that directory the active directory by using the **cd** command. The GLOSI executable (*xglosi_d*) can then be run by typing its name if the location of the executable is in the user's PATH. If the executable is not in the user's PATH, it can be executed by writing out the full path of the executable relative to the active directory. It is highly recommended that the output be directed to a file, rather than the screen by adding > *filename* after the GLOSI execution command. Persons who are more familiar with UNIX may also use the *nohup* and *time* commands to catch the output, and may wish to run the program in the background using the & command. GLOSI may take a long time to finish its calculations, depending on the number of modes being analyzed. Operation on non-standard UNIX and Linux platforms may be substantially different. A script of the setup, execution, and analysis of an actual GLOSI calculation is shown below. The output that GLOSI places on the screen has been removed to save space. It is recommended that users save this output using either the **script** or **nohup … &** commands. An explanation of these commands can be viewed by typing **man script** or **man nohup** at the command prompt.

```
Script command is started on Wed Aug 21 11:04:23 EDT 2002.
$ ls -l ../xglosi _d ../xplt1d
-rwxr-x---   1 arj      visitor  1169426 Jul 09 12:15 ../xglosi_d
-rwxr-x---   1 arj      visitor  1336535 Jul 09 12:15 ../xplt1d
```

```
$ ls
glosi.in       glosidemo.txt  menard         plt1d.in
$ ../xglosi _d
STOP 0
$ ls
glosi.in       glosi.plt      glosidemo.txt  menard         plt1d.in
$ ../xplt1d
 PLPLOT version is 4.99i

Plotting Options:
 < 1> xwin       X-Window (Xlib)
 < 2> tk         Tcl/TK Window
 < 3> xterm      Xterm Window
 < 4> tekt       Tektronix Terminal (4010)
 < 5> tek4107t   Tektronix Terminal (4105/4107)
 < 6> mskermit   MS-Kermit emulator
 < 7> versaterm  Versaterm vt100/tek emulator
 < 8> vlt        VLT vt100/tek emulator
 < 9> conex      Conex vt320/tek emulator
 <10> dg300      DG300 Terminal
 <11> plmeta     PLPLOT Native Meta-File
 <12> tekf       Tektronix File (4010)
 <13> tek4107f   Tektronix File (4105/4107)
 <14> ps         PostScript File (monochrome)
 <15> psc        PostScript File (color)
 <16> xfig       Xfig file
 <17> ljiip      LaserJet IIp/deskjet compressed graphics
 <18> ljii       LaserJet II Bitmap File (150 dpi)
 <19> hp7470     HP 7470 Plotter File (HPGL Cartridge, Small Plotter)
 <20> hp7580     HP 7580 Plotter File (Large Plotter)
 <21> lj_hpgl    HP Laserjet III, HPGL emulation mode
 <22> imp        Impress File
 <23> null       Null device

Enter device number or keyword: 15
Enter desired name for graphics output file: glosidem.ps
Created glosidem.ps
 bzmax= 0.4513500035
STOP 0
$ ls
glosi.in       glosi.plt      glosidem.ps    glosidemo.txt  menard
plt1d.in
$

Script command is complete on Wed Aug 21 11:05:47 EDT 2002.
```

The above script shows the setup and execution of GLOSI, followed by the execution of the GLOSI diagnostics tool, *xplt1d*. The commands are explained below.

1) **`ls -l ../xglosi_d ../xplt1d`** – The user uses the **`ls`** command to list files in a directory. The **`-l`** flag indicates that detailed information is to be given on these files. The next two statements indicate that only information about the *xglosi_d* and *xplt1d* files is to be shown.

The `../` preceding each of the filenames indicates that the files are in the parent directory of the current, working directory.

2) **`ls -`** The **`ls`** command again lists files in a directory. In this case it shows that only four files — *glosi.in*, *menard*, *plt1d.in*, and *glosidemo.txt* — are present in the active directory. The *glosidemo.txt* file is the name of the script that the user created in order to save the output and commands used.
3) **`../xglosi_d -`** GLOSI is run by typing its pathname relative to the active directory.
4) **`ls -`** The contents of the directory now include the *glosi.plt* file.
5) **`../xplt1d -`** The GLOSI diagnostics tool is run in the same manner as GLOSI was, by typing its pathname relative to the active directory. As can be seen, the program prompts the user to select a method of displaying information. By typing **`15`** the user chose color PostScript output, and then named the file *glosidem.ps*.
6) **`ls -`** The contents of the directory now include the *glosidem.ps* file.

For more information on how to use these commands, please consult a UNIX guide. The commands can also be researched using the UNIX command **`man`**. Simply type the name of the command after **`man`**. For example, **`man ls`** can be used to learn about the **`ls`** command. The **`man`** command itself can be explained by typing **`man man`**.

OUTPUT

GLOSI can produce three output files, although not all at the same time. These files are *glosi.plt*, *impede.plt*, and *zsave*.

GLOSI.PLT

The *glosi.plt* file is produced when the *impedance* switch is set to 0. It contains the data for all of the calculations performed by GLOSI and can be interpreted graphically using the *xplt1d* program.

IMPEDE.PLT

The *impede.plt* file contains the impedance data for the plasma analyzed and is only produced when *impedance* is set to 1. This is one of the input files used in the RANT3D code

and can be quite large depending on the number of iterations performed. This is in turn determined by the number of modes used. The file can more or less only be effectively analyzed using RANT3D. For more information on RANT3D, see "Introduction to RANT3D," by Adam Griffith.

ZSAVE

This file is also output when *impedance* is set to 1. I do not know what it is used for. It is an encoded file.

DIAGNOSTICS

There are two ways to analyze the two main output files from GLOSI, and each requires the use of another program.

XPLT1D

This program analyzes the *glosi.plt* output file for cases when only one mode is analyzed. It is used by activating the executable in a directory containing the *glosi.plt* file along with a *plt1d.in* file. The program displays 23 different options, most of which will be useless to users. The options correspond to different ways to display plots of the data held in the *glosi.plt* file. The options that should be used are 14 or 15, which correspond to monochrome and color PostScript files. The plots derived from the data are output to the designated file and may then be viewed; although, the viewing of the files may be somewhat challenging for those not familiar with all of the related physics.

RANT3D

As mentioned before, RANT3D is used to analyze the *impede.plt* file. RANT3D performs calculations on the impedance data held in the file to analyze plasma/antenna coupling. See "Introduction to RANT3D," for more information on this program.

SAMPLE INPUT FILES

Two sample GLOSI input files have been provided below. The first, *glosi.in*, is the input file used for the analysis of NSTX Shot #107899. The second is a truncated version of the *menard* file whose data comes from the same NSTX shot. It has been truncated to show the beginning, middle, and end of the file. The *plt1d.in* file used by the *xplt1d* program is also provided.

GLOSI.IN

```
&INPUT
impedance=1,
ipvm=0,
nproc=7,
isigma=1,
ileft=1,
iright=3,
xant2=.65718,
rmaj=0.92312,
rmin=0.65718,
xleft= 0.001,
xright=.65718,

aperiod=0.88,
rperiod=1.5803,
mstart= -2,
mstop=  2,
nstart= -3,
nstop=  3,

itprof=9,
t0s=3*1.3e3,
tlims=3*97.,
efoldt=0.303,
xefoldt=0.996

idprof=20,

improf=4,

tolode=1.e-4,
ninit=1000,
mxgrid=20000,
frf=30.e6,
eta=1., 0.95, 0.05,
ms= 1., 2., 1.,
qs=-1., 1., 1.,

ibyprof=20,
ibzprof=20,
bzsign=-1,
/
```

MENARD

```
277
0.2 2.38E+18 -1.898 0.191
0.205 2.4425E+18 -1.854 0.1965
0.21 2.505E+18 -1.81 0.202
0.215 2.5675E+18 -1.766 0.2075
0.22 2.63E+18 -1.722 0.213
0.225 2.6925E+18 -1.68525 0.21325
0.23 2.755E+18 -1.6485 0.2135
0.235 2.8175E+18 -1.61175 0.21375
0.24 2.88E+18 -1.575 0.214
0.245 2.9425E+18 -1.54725 0.21425

*** TRUNCATION ***

0.99 1.15323E+19 -0.424 0.0095
0.995 1.154E+19 -0.422 0.00725
1 1.15525E+19 -0.42 0.005
1.005 1.1565E+19 -0.41775 0.003
1.01 1.15792E+19 -0.4155 0.001
1.015 1.15946E+19 -0.41325 -0.001
1.02 1.161E+19 -0.411 -0.003
1.025 1.16308E+19 -0.409 -0.005
1.03 1.16517E+19 -0.407 -0.007
1.035 1.1675E+19 -0.405 -0.009

*** TRUNCATION ***

1.54 2.74529E+18 -0.246 -0.122
1.545 2.36519E+18 -0.245 -0.12125
1.55 1.97953E+18 -0.244 -0.1205
1.555 1.58266E+18 -0.243 -0.11975
1.56 1.16882E+18 -0.242 -0.119
1.565 7.44067E+17 -0.24125 -0.11825
1.57 3.78547E+17 -0.2405 -0.1175
1.575 1.45605E+17 -0.23975 -0.11675
1.58 2.45904E+16 -0.239 -0.116
1.5803 0.0E0 -0.239 -0.116
```

PLT1D.IN

```
&INPUT
 iall=-1,
 iswap=2,
 k21max=0.,
 k22max=-1.,
 k23max=0.,
 exmax=0.,
 eymax=0.,
 ezmax=0.,
 epmax=0.,
 emmax=0.,
 ejmax=0.,
 pabsmax=0.,
 psmax=0.,
```

```
sxmax=0.,
denmax=0.,
tmax=0.,
bzmax=0.,
kzmax=0.,
/
k21max=500.,
k22max=200.,
k22max=100.,
k21max=1.e3,
k22max=1.e2,
ejmax=-1.,
pabsmax=-1.,
psmax=-1.,
sxmax=-1.,
denmax=0.,
tmax=0.,
bzmax=0.,
idev=3,
```

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* This email will be changed to argriffi@alumni.rice.edu shortly after Adam's graduation in May, 2003. If argriffi@rice.edu does not work, try argriffi@alumni.rice.edu.

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