CSI 769 Fall 2010
Solar and Heliospheric Physics

Project: Potential Field Source Surface Model of Solar Corona

Assignment date: Oct. 03, 2010
Due date: Oct. 21, 2010

1. Introduction

Solar corona is a highly structured atmosphere that consists of a myriad number of curved loops. Magnetic fields in the corona play the essential role in setting up these structures. The dynamic nature of these structures provides the incessant heating of the corona, and also produces intermittent violent activities such as CMEs and flares. In this project, you are required to calculate the three-dimensional coronal magnetic fields and visualize them. The calculation will be based on the assumption of potential field, the so called potential field source surface model (PFSS).

This project will use the PFSS model developed by Mark Derosa and Karel Schrijver from Lockheed Martin Solar and Astrophysical Lab (LMSAL). The model suite includes the calculation of spherical harmonics coefficients, 3D magnetic fields, and a visualization software. M. Derosa provides an online document for his model (reference 1). The model is provided to you through Solar Software (SSW) package installed in the SSW server at Space Weather Lab (SWL). The appendix describes the access to SSW and PFSS. It also describes how to install several supplement files needed for the project. All codes are written in Interactive Data Language (IDL).

2. Description

Students are required to calculate, study and visualize the coronal magnetic field of one of the following two Carrington rotations (CR): (1) CR1984 during the solar maximum and (2) CR2065 during the solar minimum. CR1984 has a starting date of 2001/12/10 and ending date of 2002/01/07, while CR2065 has a starting date of 2007/12/29 and ending date of 2008/01/25 (reference 2). Students are advised to form two groups, one working on the solar maximum corona, while the other on the solar maximum. While discussion and collaboration among students are permitted, the project tasks and the writing of the project report shall be carried out independently.

(1). Task 1 - Getting Familiar with PFSS

This is to use the PFSS GUI (Graphic User Interface) to get you familiar with the result of a PFSS model. Once you are in SSW IDL, launch the GUI

```
IDL> pfss_viewer
```

An IDL GUI window will pop out. It is for choosing the date and time. For solar maximum group, choose 2002/01/01 00:04:00 UT, and for solar minimum group, 2008/01/01 00:04:00 UT. The B(r,theta,phi) results have been pre-calculated and stored at LMSAL computer, and the data will be downloaded on the fly. In LMSAL, the coronal B has been pre-calculated in a cadence of every four hours from 1996 onward, using the

assimilated magnetogram data (reference 3). In their model, the input synoptic magnetogram (the lower boundary condition) is improved in two aspects: (1) the snapshot magnetogram closest to the calculation time is assimilated to replace the sub-solar patch (~60 deg west to ~60 deg east) in the traditional synoptic map, and (2) a prescribed surface flux evolution model is applied to the data in order to better match the surface magnetic field on the backside of the Sun.

In the date-choosing window, click on "load", a "PFSS preview" window will pop out, which will display the synoptic chart on the left and the snapshot disk image on the right. The default disk image is as viewed from the Earth. But one could choose a different viewing angle by changing the "Projection Centroid" "L0" and "B0". Click on "Draw Field Line" button will launch the "PFSS Field Line Render" window to show the 3-D field lines.

Feel free to play with the GUI and try to render the field lines in different scenarios: (1) change the viewing angles through "Projection Centroid" parameters, (2) change field line density through "Number of Lines" parameters, and (3) change the line plotting area through "Lon/lat bounds(deg)" parameters, or drag the highlighted area corners in the "PFSS previewer" window. The white lines are for closed field, while blue and red are for open field lines, positive and negative polarities respectively.

For this task, you need to make and save (use "Save as TIFF" button) at least four images of the rendered coronal lines: (1) sub-solar view (or view from Earth), (2) 180-degree from the sub-solar view (backside of the Sun on the date chosen), (3) view from north pole, and (4) view from the south pole. For each view, you should choose an appropriate line plotting area and the number of field lines.

(2). Task 2 - Calculating PFSS Field Lines Using Command Line

This is to get you familiar with the command line PFSS model. A "pfss_sample1.pro" is provided to you. Note that this piece of IDL program is slightly modified from the original version located at "/ssw/sswidl/packages/pfss/idl/pfss/". Open the program in an editor and study each of the lines of the code carefully. In the data restore block (the beginning part), choose or type in "pfss_restore, pfss_time2file('2002-01-01')" if you work on solar maximum corona, and save the file. Run the program at the SSW IDL command line

```
IDL> .run pfss_sample1
```

The date of the B-field will be downloaded from LMSAL in real time, and saved in a cache at ("/tmp/"); there is no need of downloading if the same data request is made. The rendered image of the coronal field lines will pop out. The control of the field line density and the seed points (the starting points of the lines) are made through the program "pfss_field_start_coord.pro". The rendering of the plotting, including the viewing angles is made through "pfss_draw_field.pro". You need to get familiar with these programs and the associated control parameters (so-called keywords in IDL), in order to render the image.

Again, for this task, you need to make and save at least four images of the rendered coronal lines: (1) sub-solar view, (2) 180-degree from the sub-solar view, (3) view from north pole, and (4) view from the south pole. For each view, you should choose an appropriate line plotting area and the number of field lines to be plotted. To save the image in command line, for example in "gif" format, type:

```
IDL>write_gif,'myplot.gif',tvrd()
```

(3). Task 3 - Calculating PFSS Model With Your Own Input

The last task is to calculate your own coronal model using your own input of synoptic magnetogram. Open in an editor and study the program "pfss_sample2.pro" provided to you. The input magnetogram is the traditional Carrington synoptic charts, but made by SOHO/MDI team in a high-resolution format (3600 pixel in longitude and 1080 pixel in latitude (for an introduction, refer to http://soi.stanford.edu/magnetic/index6.html). All these charts in FITS data format have been downloaded and stored in the local data server at SWL (at "/swd/data/soho/mdi/synoptic/carrot/M/"). In "pfss_sample2.pro", the default is for CR1984. If you work on CR2065, you need to change the assign line as

```
synop='/swd/data/soho/mdi/synoptic/carrot/M/2065/synop_Mr_0.2065.fits'
```

As described in the program, "pfss_mag_create.pro" is to pre-professing the boundary condition. "pfss_get_potl_coeffs.pro" is to compute spherical harmonic coefficients of the potential field. "pfss_potl_field.pro" is to compute the magnetic field B(r,theta,phi) given the coefficient. Note that, it takes about a few hours to run the step of "pfss_potl_field". All these calculation programs are located in the PFSS package at "/ssw/sswidl/packages/pfss/idl/pfss/".

To calculate your own magnetic field, simply in SSW IDL, type in

```
IDL>.run pfss_sample2
```

The calculated magnetic field will be stored in a local IDL save file named as "pfss_my_data.sav". To visualize the data, you need to modify the "pfss_sample1.pro" program to un-comment the line "restore,'pfss_my_dats.sav'", and then type in

```
IDL>.run pfss_sample1
```

which will carry out the field line rendering as described in task 2.

Again, in this task, you need to make at least four images as in other tasks.

3. Submission

You need to submit a succinct project paper with the following components. (1) A description of the PFSS model, including the main mathematical functions that control the model and the boundary conditions. (2) A description of the results from task 1, 2 and

3. The plots you made in these tasks should be included. The plots need to be properly labeled. Briefly discuss these plots in the context of the understanding of the solar corona, e.g., active region fields, coronal hole fields, multiple-loop arcades from mixed polarities et al. It is not surprising if the corresponding plots from the three tasks are similar. Please discuss if there are any differences. The report should be written in WORD, or convert to PDF if in different format. Only electronic version of the report is accepted.

Reference:

1. SSW PFSS model information page from M. Derosa:
http://www.lmsal.com/~derosa/pfsspack/
2. Carrington Rotation Table: http://soi.stanford.edu/magnetic/cr_table.html
3. Assimilation model: "Photospheric and heliospheric magnetic fields", Schrijver & DeRosa (2003) SPh, 212, 165
4. Original PFSS model: "A model of interplanetary and coronal magnetic fields", Schatten, Kenneth H.; Wilcox, John M.; Ness, Norman F., Solar Physics, Volume 6, Issue 3, pp.442-455

Appendix: Access SSW PFSS at GMU

To use SSW at Space Weather Lab. Create an account in "helio.gmu.edu". If you work from home, you need to log-in to "helio" using "ssh" from an X-window in your local machine. If you work at the lab, please try to use other computers other than "helio", to prevent the overloading of "helio".

Set up the SSW and PFSS environment. copy "ssw.cshrc" file (provided) into your home directory in "helio" (using "scp" if working remotely, or downloading if working locally). Rename "ssw.cshrc" as ".cshrc" in the home directory.

How to Start SSW IDL.

```
%csh
%ssw
%sswidl
```

Programs other than in PFSS packages. For this project, you are advised to create "pfss" directory in your home directory, and copy the following four files into this directory. Also start "sswidl" in this directory

(1) "pfss_sample1.pro", replace the one from PFSS package
(2) "pfss_sample2.pro"
(3) "pfss_mag_create.pro", replace the one from PFSS package, in order to handle MDI high-resolution synoptic charts
(3) "pfss_potl_field.pro", replace the one from PFSS package, in order to save the calculation results in the local directory.

SSW at SWL. "%cd /ssw/sswidl"

SSW PFSS at SWL. "%cd /ssw/sswidl/packages/pfss/idl/pfss/"

SSWDB at SWL. "%cd /ssw/sswdb"

MDI Synotic Charts at SWL. "%cd /swd/data/soho/mdi/synoptic/carrot/M/"