CISM Center For Integrated Space Weather Modeling

Summer School Lab Activities

Lab #1: Introduction to Visualizing Space Physics Models

Introduction

The goal of this lab exercise is to provide an overview of the visualization of some space weather models along with the basic commands that are used to manipulate one of the visualization packages we use, CISM-DX.

Goals: When you are done with this lab you should:

- recognize the importance of visualizations in understanding results of complex simulations
- be able to describe the gross structure of the solar magnetic field, the solar wind, and the magnetosphere.
- become familiar with visualization tools such as field lines and cut planes.
- gain experience with visualization interactions: rotate, pan & zoom, adjust visualization parameters

Activity 1: Visualizing Magnetic Field Lines in the Solar Corona using the MAS Model

We will begin by exploring the structure of the magnetic field of the sun during solar minimum. The data we will use is from Carrington Rotation 1912 (CR1912 – late July and early August of 1996. see http://umtof.umd.edu/pm/crn/). A computer model called "Magnetohydrodynamics Around a Sphere" (MAS) was used to calculate the field structure and plasma parameters based on the magnetogram for the surface of the sun during CR 1912.

Before You Begin:

Before you begin exploring the simulation results, discuss the following two questions with your group.

- ***What do you think the solar magnetic field will look like during solar minimum? Sketch your answer to share with everyone.***
- ***What other results could most likely be obtained from the MAS output?***

Using OpenDX (CISM-DX)

First we need to switch to the directory with the lab 1 files in it and then load CISM-DX. You can do this from your home directory by typing at the prompt:

```
[user@localhost ~]$ cd swss-labs
[user@localhost ~]$ cd lab1
[user@localhost ~]$ cismdx &
```

This will cause the "**Data Explorer Visual Program Editor (VPE)**" to open. The VPE is the way programs are written in OpenDX. The CISM-DX network we will use for visualizing the MAS results is called MAS.net. To load this network,

- single click the **File** menu and choose **Open Program…** option.

- select the ***MAS.net*** file
- click **OK**

You can see many boxes on the VPE canvas connected together by black wires. Each box can be thought of as a separate subroutine or function that completes one step in process of producing the final visualization. Using the VPE to create programs would require much more time than we have for this lab so we are just going to concentrate our efforts on using predefined networks. If you want more information about Data Explorer you should visit http://www.opendx.org/

Executing a visual program

Now that we have the program loaded let's make it do something:

1. Click on **Execute** in the menu bar of the VPE window.
2. Select **Execute Once** in the pull-down menu. Execution (which may take several seconds) is indicated by the highlighted ***Execute*** in the menu bar and the brief highlighting of various icons in the canvas area.
3. Note: A visual program can be executed from any window that has ***Execute*** in its menu bar. This command can also be issued by typing **Ctrl-E** while the mouse is in either the VPE or the "**Image"** window. ((be sure that "Numlock" is off)

The window that appeared depicts the magnetic field of the Sun. In the middle there is a blue and red sphere that depicts the polarity of the radial component of the magnetic field at the surface of the Sun. Blue is one polarity (say "in") while red is the other polarity (say "out"). The magnetic field extends out to the simulation boundary of 30 solar radii (approximately 20 million kilometers).

The initial image is very small so two tools will be used to adjust the view: **Pan/Zoom** and **Rotate**. To do this we will use the "**View Control"** dialog box which can be opened by selecting "**View Control"** in the "**Options"** pull-down menu in the Image window.

The "**View Control"** dialog box allows you to control (among other aspects of an object) the following:

- Viewing direction
- Rotation
- Field of view (zooming and panning).

Controlling the Field of View

Pan/Zoom mode allows you to change the center of focus while zooming in or out:

1. Select **Pan/Zoom** in the ***Mode*** option list of the "View Control" dialog box.
2. To zoom in, position the mouse cursor at the point in the ***Image*** window that you want as *the center* of the new "picture", then using the left mouse button, click and drag the box out to cover the interesting portion of the image.
3. To zoom out, do the same as above but use the right mouse button, and drag out to define the region that the current image will occupy. When zooming out, the image in the image is shrunk to the size of the rectangle (though the Image window remains the same size).
4. Two hot keys are helpful (be sure that "Numlock" is off):

- **Ctrl-Z** to undo the most recent action.
- **Ctrl-F** to reset the view to a default view

NB: You can get to the ***Pan/Zoom*** Mode by typing **Ctrl-Spc** in the ***Image*** window.

Controlling the Viewing Direction

To change the viewing direction, select **Set View** in the dialog box. This list includes a set of head on views (top, front, left, etc.) and a set "off angle" view directions (off top, off bottom, etc.). When you select a view of an object, the image is automatically altered (note the highlighted Execute in the menu bar).

Rotation

To rotate an object in the Image window, first click on the **Mode** option box and select **Rotate** from the displayed list (note: ***Rotate*** becomes the current mode and a set of axes appears in the lower right-hand corner of the window). The positive "z" direction is roughly pointing in the same direction as the rotational axis of the sun. You can rotate the object in two dimensions (clockwise and counterclockwise) or in three by rotating the axes. You can also cause the object to rotate "instantaneously" (i.e., in coordination with the axes).

2-D Rotation:

Position the mouse cursor in the Image window and hold down the right mouse button: clockwise movement of the mouse around the center of the image produces clockwise rotation of the axes; counterclockwise movement produces counterclockwise rotation. When the mouse button is released, the object rotates by the same amount as the axes have, assuming the same relative position in the window.

3-D Rotation:

Position the mouse cursor in the Image window and hold down the left mouse button: the mouse now behaves like a track ball and the axes move accordingly. When the mouse button is released, the object rotates by the same amount as the axes have, assuming the same relative position in the window.

Continuous Rotation:

Once you have selected ***Rotate*** mode, you can make the object rotate continuously rather then just when you release the button: select **Execute** in the menu bar and then **Execute on Change** in the pull-down menu (Execute is highlighted). Now the image rotates continuously as the mouse is moved.

NB:

1. Turn off ***Execute on Change*** by selecting **End Execution** in the ***Execute*** pull-down menu.
2. To restore the original view of the object, select **Reset** in the ***View Control*** dialog box.
3. You can get to the ***Rotate*** Mode by typing **Ctrl-R** in the ***Image*** window.

Structure of the Solar Magnetic Field

Using the Pan/Zoom and Rotate features, try to understand the overall structure of the solar magnetic field at solar minimum. Sketch a cartoon version of the solar magnetic field in your lab notebook that includes all of the main features. Discuss the following questions with your group and be prepared to discuss them with the class.

- ***Can you classify different types of magnetic fields lines?***
- ***What can you say about where field lines originate and end on the Sun?***
- ***What other variables might you like to view that would help you understand the solar corona environment better?***

Activity 2: Using Cut Planes to Visualize the Solar Wind in the Enlil Model

The Enlil model uses MHD to simulate the solar wind plasma. It is named after the Sumerian god of wind. For the simulation results we will look at here, the inner boundary is at 21.5 solar radii (R_s) and it has a spatial resolution of 0.5 R_s in the radial direction and 1-2 degrees angular resolution. The model is driven by the plasma parameters from a corona model such as MAS or the Wang-Sheeley-Arge (WSA) model.
Before we begin:

- ***In what direction do you think the solar wind flows?***
- ***How would you describe the structure of the Interplanetary Magnetic Field (IMF)?***

To explore the solar wind, close the image window and, in the Visual Program Editor (VPE) window, go to the **File-> Open Program… [click 'No' when asked if you want to save; you do not have permission]**. Select the "ENLIL.net" file from the file selection window and click 'ok'. Execute this network [choose **Execute Once** from the **Execute** menu].

The window that appears depicts a nearly ecliptic (in the plane of Earth's orbit) cut plane colored with the values of a plasma parameter. The Earth's position is marked by a red cube and is about the size of the Earth's magnetosphere. The initial parameter colored on the cut plane should be the log of the plasma density and the caption on the color bar should read "Log(Den)". If it does not, don't worry about it right now; we will change it soon. The hole in the middle of the cut plane represents the inner surface of the simulation. Notice that the window also shows a color bar on the side that translates color into values. The scale on this bar will change, but blue will always be the lowest value and red will be the highest. Finally, there is a green sphere marking the position of earth. Use the "Pan/Zoom" and "Rotate" features that you learned about in the last section along with adjusting the window size to get a view you are happy with.

Like all MHD codes, ENLIL calculates and can output a variety of plasma parameters for each spatial point in the simulation including: plasma density, plasma velocity, plasma temperature, and magnetic field. To view different plasma parameters, in the ***Image*** window, choose **Windows->Open Control Panel by Name** and choose the ***Plasma Parameter*** panel. A control panel should open with a "Selector" drop down menu in it. Click on the drop down menu and choose "Log(Den)" if it is not already chosen and execute the net.

- ***Why is the log of the density used for the color map rather then just the density?***
- ***Do you notice any structure in the plasma density? How does it change radial? How does it change azimuthally? What do you think causes the structures you***

see?

- ***Make a sketch of it in your notebook.***

Use the drop down menu to choose the absolute value of the plasma velocity (|V|) and execute the net. Observe the change of scale on the color bar. The units here are in km/sec.

- ***What structure do you notice in the plasma velocity? How does it change radially? How does it change azimuthally? What might be the cause?***
- ***Again, make a sketch of it in your notebook.***
- ***Can you draw any general conclusions about the relationship between the plasma velocity and the density? How would you modify this image to help understand it better?***

You can also explore other plasma variables now, though this will be done in more detail in a future lab.

Activity 3: Using "Interactors" in Visualizing the Magnetosphere using LFM Model

Now we will look at the results from a geospace simulation. The Lyon-Fedder-Mobarry Model (LFM) simulates the space plasma and magnetic field near the Earth. Because of the strong coupling between the ionosphere and the space plasma, this model must include a simulation of the Earth's ionosphere.

Again, before looking at this:

- ***Sketch a picture of the magnetic field around the Earth.***
- ***Describe what happens to the solar wind when it encounters this field.***

Start by loading the LFM.net file (**File->Open** and select the LFM.net file). Before executing this network we want to check some settings. From the **Windows** menu choose **Open Control Panel by Name** and then choose the **Main Panel** from the list. This will have three selectors in it. The file selector should have the word "*west*" in the file name. The "**Plasma Parameter**" should be set to "*Density*" and the "**Plasma Vector**" should be set to "*B*" which is the magnetic field.

Execute the network. An image window will appear that shows both magnetic field lines and cut planes colored with plasma density. This is an "idealized" (made up) case with the interplanetary magnetic field pointing purely westward.

- ***Identify the position of the Earth and the direction of the Sun. What direction do the x and z axes correspond to?***

Explore this image using the **Pan/Zoom** and **Rotate** tools.

- ***How would you describe the structure of the magnetic field?***
- ***Where is the plasma density the highest? Where is it the lowest?***
- ***Can you identify the bow shock and the magnetopause? How?***

In the **Main Panel** window, replace the word "west" with "north" in the "filename" selector (and hit **<Enter>**) and execute the net. Now the solar magnetic field will be pointing purely northward. (What direction does the Earth's magnetic field point in?)

- ***Describe the changes you see in the magnetic field and the plasma density.***
- ***How has the situation changed at the bow shock?***

Now replace the word "north" with "south" (and hit **<Enter>** and execute the net).

- ***Again, how does the situation change? Be prepared to compare northward pointing field to the southward pointing field.***

Saving and Sharing

To help discussions it will be useful for you to be able to save some of the images you have seen on the screen so that others can view them later. For this activity you may use any of the networks that we have used in this lab to choose an image that you think shows a particularly interesting issue that you would like to discuss. Choose an image that either:

- shows a phenomena that you think is interesting

or

- illustrates something that you think is missing in the visualization.

In the "**Image**" window choose the **Save Image** option from the "**File**" menu (**File -> Save Image**). A dialog window will appear that allows you to select a number of options for saving the image. You will not be allowed to save into the default directory so we will have to navigate into a directory you can save into.

- Click on **Select File…** to bring up a file browser
- In the "**Directories**" browser of the "**Save Image to File**" dialog window, double click on the parent directory whose label ends in "**. .**"**.** If you do this twice it should bring you up to your home directory ("/home/swss07/[username]").
- In the "**Selection**" entry finish the file name by typing "**myimage**" or some other name at the end.

You should be able to save into this directory. Now we need to change some of the other settings.

- For the format pull down select **TIFF**
- Select **Save Current**
- Click on **Apply**

You should now have an image file in your home directory. To check, on a UNIX system go to the "**Places**" menu at the top of the computer screen and choose the "**Home**" folder. Your image should be in that list. If you double click on it, it should open up.