Solar Wind Variation Throughout the Heliosphere

Goals:
In this lab you use simulation results to explore the structure of the solar wind.
When you are finished with this lab you will have reviewed:
- the variation in solar wind plasma parameters as a function of distance from the sun
- the relationship between plasma flow and the magnetic field line topology
- the variation in solar wind plasma parameters as a function of solar latitude
- the difference in the overall structure of the solar wind between the solar minimum case to the solar maximum case
- the interaction of fast and slow solar wind flows

Before You Begin:
- *How should the various plasma parameters of the solar wind change with distance from the sun? In particular, consider: density, speed, magnetic field strength.*
- *How would you describe the overall flow of the solar wind? What direction does it flow in? Does the direction change as it moves further from the sun?*

Part I: An Overview of the Solar Wind

Introduction
The iSWA layout below shows simulation results from the solar wind Enlil model. A brief description of the Enlil model can be found here, http://ccmc.gsfc.nasa.gov/models/modelinfo.php?model=ENLIL.

http://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/index.jsp?i_1=169&l_1=9&t_1=302&w_1=681&h_1=451&s_1=2013-07-01%2011:01:25.0_0_10_3&i_2=167&l_2=694&t_2=298&w_2=693&h_2=455&s_2=2013-07-01%2011:01:25.0_0_10_3

- *What solar wind variables are you viewing in the iSWA layout? What range of values do they take?*
- *What other features are represented in the plots?*
- *What other variables mighty you expect from the Enlil model?*
- *What other information would you like from the model?*

Cut Planes
The two cygnets in the layout above show cut planes through a 3-D volume of simulation results for a given variable - density and velocity.
- *On your groups shared pad, sketch the 3-D simulation volume showing the cut planes.*
- *Can you describe the volume?*
- *Why do you think this volume was chosen by the model developers?*

Each cut plane is painted with a variable that is derived from the simulation results.
- *What is the scale (range) of the velocity variable?*
- *How is the "density" plotted? What simulation results are used to calculate it?*

- *What is it's range? What is the expected density at 1 AU (Earth's orbit)?*

Variation in Density and Velocity
- *Describe how density and velocity vary with distance from the Sun.*
- *Can you explain these results in terms of fundamental physics?*

Consider just the velocity cygnet.
- *What is the direction of the velocity (say relative to the radial direction) as you move away from the Sun? Does the direction change further from the Sun? Why?*
- *What simulation results would you want to look at to answer this questions?*

Be prepared to discuss your group answers with the whole room.

Part II: A Second Look

Variation in Density

In this section you will look at the density and velocity variations in more detail.
Go to this page
http://ccmc.gsfc.nasa.gov/database_SH/Nicholas_Gross_052511_SH_2.php

These are simulation results from the Enlil solar wind model for Carrington Rotation (CR) 2060. CR 2060 starts in the August 15, 2007 and runs to September 11, 2007. This is a period of low solar activity near "solar minimum".

- *Click on the "3D Data" link.*

This links to a form page that allows the user to plot the simulation results in a variety of formats.
- *To start with click "Update Plot"*

You should see a plot very similar to the the plots you just looked at.

Keep this Window available on a separate computer for reference as you continue.

Now though we can also plot the data along a line.
Scroll down the form and choose the following settings:
- *From the "Plot Mode" drop down menu choose "Line 1D"*
- *From the quantities drop down menu choose:*
  Q1: "N", Q2 "B" , Q3 "N" (to keep it from plotting anything)
- *In the "Choose Plot Area", set "Lon1","Lon2", "Lat1", and "Lat2" to "0"*
- *Hit the "Update Plot" button*

You should now have a line plot showing the variation of the density and magnetic field strength along a radial line in the solar equatorial plane.
- *Where is this line in the equatorial plane that you plotted previously? Sketch it on your shared workspace.*
- *Compare the variation in the magnetic field to the density. Are they related? Why?*

- *Can you tell how the density varies with distance from the Sun? What would help?*

- *Now scroll down to "Plot Options" and select "Log scale" under "Color Contour, (Vertical) Line", then hit "Update Plot"*
- *Does this help you answer the questions above?*

Rescaled Density
Finally, let's look at a rescaled density.
- *Choose "Q1: Nr^2" and set Q2 and Q3 to the same so one only look at one variable*
- *You may want to turn off the "Log scale" option.*
- *How would you describe this plot? How does it vary with distance from the Sun?*
- *What general conclusions can you draw about how the density varies with distance from the Sun?*

A Second Look at Variation in Velocity
Look at the components of velocity.
- *From the quantities drop down choose: Q1: "V_r", Q2 "V_lat" , Q3 "V_lon" and update the plot.*
- Over what range do each of the components vary?
  - Range for V_r
  - Range for V_lat
  - Range for V_lon

- What does this say about the general direction of the solar wind velocity?
- How does the solar wind vary with distance from the Sun?

Finally let's look at the correlation between the solar wind velocity and plasma density.

- *From the quantities drop down choose: Q1: "N*r^2", Q2 "V_r" , Q3 "V_r" and update the plot.*
- Are the velocity and density correlated? When the velocity is high what happens to the density? When the velocity is low? During the transition from high to low?

Traffic Jams: Evolution of Co-Rotating Interaction Regions (CIR)

Revisit the 2-D plot of the equatorial cut plane that plots density.
- *You may want to zoom in some by changing "R2" in "Plot Area" to "5".*
- *Notice spiral structure of Co-Rotating Interaction Regions*

Track the structure of one of these regions at different distances from the Sun.
- *Back on the line plot, change "R2" to "5", and "Lon1" and "Lon2" to "135"*
- *Describe the structure that you see of the region closest to the Sun.*
- *Decrease the longitude value by intervals and see how the structure evolves. You may want to have different plots on different screens at the same time.*
- *Describe how the structure changes as it moves out from the Sun.*
- *How far from the Sun is the CIR when it develops into a Shock?*