Magnetosphere 1:
A Different Magnetosphere

Introduction

This lab will use model results to explore how changing parameters of the magnetosphere - dipole strength and dipole tilt - will change or not change the character of the magnetosphere and its interaction with “typical” solar wind conditions at 1 AU.

Before you begin we need to agree on some definitions for regions in the magnetosphere. As a group, define how you would identify the following features using results from simulations:

- the leading edge of the bow shock
- the magnetopause
- the width of the magnetosheath
- the reconnection point (assuming the solar wind IMF is southward)

Be sure that your definitions reference plasma parameters derived from simulation results. Be prepared to discuss these with the whole group.

Driver of the Magnetosphere: The Solar Wind

Before looking at the simulation results directly, compare the idealize solar wind that is used to drive these simulations with the real solar wind. This link is to a table of runs for different dipole strengths.
http://ccmc.gsfc.nasa.gov/support/HSS_2015/consolidated.php
The table not only provides links to the run outputs, but also gives you the run parameters. Notice that the solar wind conditions for all the runs are the same. “Dm” refers to the dipole moment of the Earth.

- What aspect of these solar wind conditions are unrealistic? (Here is a link to the solar wind conditions measured by ACE over the last 7-days http://www.swpc.noaa.gov/ace/MAG_SWEPAM_7d.html)

Identifying Day Side Features of the Magnetosphere

We will start by exploring changes in the dipole strength of the Earth while keeping the relative tilt at 11 degrees. Try opening each run in a different tab or window. You may want to compare one run to another.

- *Start with the “Dm=2.*Dm_earth” run. Select the “View Magnetosphere” link and then click “Update Plot”*
- ***What parameter is plotted? What units for length are being used?***
- ***Which direction is towards the Sun?***
- ***Can you visually identify the features of the magnetosphere in this image?***

Plotting Field Lines

To plot some field lines:

- In the plot mode menu choose “Color + Vector + Flowlines”
- In the Q3 menu choose one of the B components such as “Bz”
- Choose “update plot”.
- **Can you identify different types of field lines?**

Keep this image in a separate window for reference and return to the table.

Looking at Line Plots

Try looking at a line plot of some plasma variables.

- *Again choose the “Dm=2.*Dm_earth” run and select the “View Magnetosphere”.*
- *Select “Line (1D) from the “Plot Mode” drop down.*
- *In “Choose Quantities”, select quantities based on the definitions you came up with in the beginning. (One possible set is “N”, “V_x”, and “B_z”)*
- *In the “Plot Area” section, set:*
  X1 to “0” and X2 to “20”
  Y1, Y2, Z1 and Z2 to “0”
- *Choose “Update Plot”*
- From this line plot can you identify the features of the magnetosphere defined above?
- Does this plot take you directly through the “Nose” of the magnetopause?
- *Constrain the “X” variables a little to get more detail.*

- From this plot identify the position of the bow shock and magnetopause, the position of the reconnection point (“X”- point), the width and maximum density of the magnetosheath.
- How useful are the definitions identified earlier?
- Do these features occur in the order you expect them to be?

Tail Effects of Differing Magnetic Field Strengths

First we have to define what we mean by the “magnetotail”

- Discuss in your groups what features you might look for in the tail?
- Again, how do you define these features?

Be prepared to talk about this with the whole group.

Choose one of the features to explore in the tail region and begin to look for it in the simulation results.

- *Start by looking at the X-Z cut plane again.*
- *In the “Quantity” Q1 drop down menu choose the appropriate variable to explore.*
- Can you identify the tail feature you are looking for? (You may want to adjust the “Plot Area” using the “X” and “Z” values to zoom in)
- How far down the tail does the feature appear?
- *Again construct a table for the different runs and compare the results.*
- What general trends and surprises do you see?

You may want to use the line plots to investigate these values more carefully.

- How might a simple line plot mislead you?

1) Variation in Stand-off Distance with Dipole Strength

Now lets look at the other cases. Choose a few of the features to explore in the magnetosphere and look for them in the various simulation results.

- *Start by looking at the X-Z cut plane again. The easiest way to do this is to return to http://ccmc.gsfc.nasa.gov/support/HSS_2015/consolidated.php and open up each page again.*
- *Again click on each run link and choose "View Magnetosphere".*
- *In the "Quantity" Q1 drop down menu choose the appropriate variable to explore.*
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- *On the large shared work space, make a table for the values that you just collected above for all of the runs.*

- What general trends do you see in the results?
- Can you compare the trend in the simulation stand off distance to an estimation from a simple model (for example https://en.wikipedia.org/wiki/Magnetopause#Estimating_the_standoff_distance_to_the_magnetopause)? What would be the best way to plot the values to see if they were consistent with the estimate?
- Are you surprised by any of the simulation results? Which might represent a problem from a space weather point of view?

1a) Tail Effects of Differing Magnetic Field Strengths

First we have to define what we mean by the "magnetotail"

- Discuss in your groups what features you might look for in the tail?
- Again, how do you define these features?

Be prepared to talk about this with the whole group.

- Can you identify the tail feature you are looking for? (You may want to adjust the "Plot Area" using the "X" and "Z" values to zoom in)
- How far down the tail does the feature appear?
- *Again construct a table for the different runs and compare the results.*
- What general trends and surprises do you see?

You may want to use the line plots to investigate these values more carefully.

- How might a simple line plot mislead you?

2) Different Dipole Tilts

Another variable we can change is the dipole tilt. This page http://ccmc.gsfc.nasa.gov/support/HSS_2015/consolidated.php has links to three runs with the dipole tilt at 11 degrees, 45 degrees and 90 degrees in the table

- *Investigate these first by using the 2D plots of the plasma density.*
- Do the structures we defined in the beginning still make sense?

- Use the definitions and tools we developed above to explore these runs. Make a table of the values ask for in the beginning. ***Do they change with the tilt?***
- Plot the field lines. ***What is the overall structure of the field?***

3) Magnetospheres in Different Locations

Before you begin, as a group discuss:
- What are the important drivers and parameters that affect the shape of the magnetosphere?
- How do these vary as you change location in the heliosphere?
- How do you expect the magnetosphere to change?

This page contains a table that places the Earth's dipole at different distances from the Sun. http://ccmc.gsfc.nasa.gov/support/HSS_2015/consolidated.php
The table not only gives links to the run outputs, but also gives you the run parameters. The "Keywords" indicate the simulated distance from the Sun, and the solar wind parameters are given.
- Is the variation in solar wind parameters consistent with what you discussed above?
- Why do the other parameters change?

Now let's look at the specific simulations.
- *Open up all of the simulation links in new tabs and click on "View Magnetosphere" and click "Update Plot".*
- *Use the "Plot Area" settings to adjust the image size.*

- Looking over all of the profiles, does the magnetosphere change qualitatively in the way you expect it to?
- What qualitative changes do you see?

3a) Quantitative Changes
- Using the "Line(1D)" plots the way you did in the last lab, identify all of the quantities that we identified previously and tabulate them as a function of distance from the sun. The included:
  - on the day side: position of the bow shock and magnetopause, the position of the reconnection point ("X"- point), the width and maximum density of the magnetosheath.
  - on the night side: how far away does the current sheet first develop, and what the maximum value of the current sheet. (You may want to go back to the 2D slices for this?)
- What general trends do you see in these features?

4) Dipole Reversal
Through out the Earth's history the dipole has changed.
The table at the bottom of this page http://ccmc.gsfc.nasa.gov/support/HSS_2015/consolidated.php lists runs that simulate this reversal. The Earth's magnetic field has

been modeled using a planetary dynamo and the dipole and quadrapole moments have been extracted from that. These moments were then used to simulate the magnetosphere. The g10 parameter indicates the strength of the north/south dipole.

- Choose one of the runs with a strong dipole moment and plot a cut plane similar to to the ones you did previously. ***Can you see all the features that you saw in the initial plots?***
- Turn on the Field lines. ***Do the field lines act as expected?***
- Now pick a case where the dipole is small and plot this in a separate window. Compare this to the previous plots. ***What do you notice? Compared to the strong dipole case, what features on the same and what are different?***
- For all the cases, use line plots to identify the bow shock and magnetopause. ***How do these change with the changing magnetic field?***
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