Solar Activity

Part 1: Observations

Introduction

In this lab you will explore structure of the solar magnetic field using visualizations of simulation results.

- compare sunspot images to the magnetograms for both solar minimum and solar maximum cases
- relate active regions as seen in magnetograms to those seen in Extreme Ultraviolet Images
- compare the properties of active regions over the course of a solar cycle

Sunspots and Solar Active Regions

1. Open the web browser bookmarks and click on the 'Solar-SOHO' link. You will see a window with 5 displays.
2. http://iswa.ccmc.gsfc.nasa.gov:8080/IswaSystemWebApp/index.jsp?i_1=71&l_1=419&t_1=269&w_1=451&h_1=373&i_2=5&l_2=662&t_2=633&w_2=395&h_2=427&i_3=4&l_3=218&t_3=644&w_3=417&h_3=428&i_4=137&l_4=15&t_4=253&w_4=388&h_4=400&i_5=139&l_5=907&t_5=261&w_5=399&h_5=409

3. Focus on the top row first (below the 'Available Cygnets' menu). On the left side is the white light image of the Sun, and on the right is the magnetogram image. These two images were taken by the SOHO spacecraft
4. (http://sohowww.nascom.nasa.gov/). Notice the date in the lower left hand side of the image. The functions of this spacecraft are being replaced by the SDO spacecraft (http://sdo.gsfc.nasa.gov/) so the most recent data is not available. Historical data is available though going back over a decade.
5. Use the 'Global Date/Time' feature to set the date to the first day of 2011. Compare the white light image to the magnetogram image. Discuss the following with your group.

   Discuss with your group:
   - ***What is the relationship between sunspots and magnetically active regions?***
   - ***Are all sunspots associated with magnetically active regions?***
   - ***Are all magnetically active regions associated with sunspots?***
   - ***How does the structure of the active region differ between the northern and southern hemisphere?***

6. The bottom two panels show images taken by the SOHO spacecraft in the Extreme Ultraviolet (EUV) range for a give wavelength. The 'blue' image is 171 Angstroms and the 'green' image is 195 Angstroms. Bright regions show areas where the

coronal plasma above the solar surface is heated to temperatures that irradiate at that wavelength. These are referred to as 'active regions'. Dark regions are are interpreted as being 'holes' in the coronal where the plasma has been evacuated.

Discuss with your group:
- ***How do the EUV active regions compare the the strong magnetic regions on the magnetogram?***
- ***Where are the coronal holes located? How do they correspond to the active regions?***
- ***Can you make out the coronal holes at the poles as well as at the lower latitudes?***

7. The last panel, in the middle of the top row, shows a computer model results of the solar magnetic field. Model results are not available for all dates so look carefully at the date to make sure the results exist.

Active Regions and Coronal Holes Throughout a Solar Cycle

8. Review this page http://www.swpc.noaa.gov/SolarCycle/ on the Space Weather Prediction Center website to determine approximately where we are in the solar cycle. You can also look at http://solarscience.msfc.nasa.gov/images/ssn_predict_l.gif from NASA.
9. Use the 'Global Date' Setting to view historical data from SOHO back to 1998. Explore how the position and configuration of the magnetic active regions changes over the course of a solar cycle. (Note that the SOHO data begins during the approach to Solar Maximum of Solar Cycle 23 while we are currently in the rising phase of Solar Cycle 24.)

Discuss with your group:
- ***What happens to the average latitude of the active regions over the solar cycle?***
- ***What are the indicators of the beginning of a new solar cycle? When does Solar Cycle 24 begin?***
- ***Is the beginning of the solar cycle occur during solar maximum or solar minimum?***

10. Review the position and configuration of the coronal holes through out the solar cycle.

Discuss with your group:
- ***Where are the coronal holes mainly located near solar minimum? Solar Maximum?***

Configuration of the Solar Magnetic Field

The last panel in the middle of the top row shows a computer model prediction of the solar magnetic field that uses the measured magnetogram as input. We will explore this further in part 2.

Viewing the Latest Data

11. Scroll through the Cygnet menu at the top of the page under the solar tab and search for the 'SDO AIA 4500' (page 5 of the solar page) data feed and the 'SDO HMI' (page 6) magnetograms. Click on each and and arrange the windows. Also choose one of the SDO composite images. Reset the global date to the current date

Discuss with your group:

- ***Based on these images, what is the current phase of the solar cycle? What are the indications you used to draw this conclusion?***

The SDO version of the page we started with is at:
http://iswa.ccmc.gsfc.nasa.gov:8080/IswaSystemWebApp/index.jsp?i_1=71&l_1=420&t_1=317&w_1=451&h_1=373&s_1=0_0_10_3&i_2=255&l_2=1&t_2=296&w_2=415&h_2=432&s_2=0_0_10_3&i_3=21&l_3=7&t_3=728&w_3=447&h_3=459&s_3=0_0_10_3&i_4=251&l_4=441&t_4=717&w_4=416&h_4=443&s_4=0_0_10_3&i_5=275&l_5=865&t_5=265&w_5=398&h_5=411&s_5=0_0_10_3&i_6=32&l_6=62&t_6=1202&w_6=1175&h_6=305&s_6=0_0_10_3&i_7=17&l_7=853&t_7=693&w_7=425&h_7=458&s_7=0_0_10_3

Solar Photospheric Magnetograms and Synoptic Maps

Magnetograms are images of the solar magnetic field at the photosphere. They are derived by measuring the size of line splitting due to the Zeeman Effect. (Electrons in the same energy level, but with different angular moment will have their energies changed slightly when a magnetic field is applied. This appears in the atomic spectrum as split spectral lines.) These magnetograms are used as the inner boundary conditions for coronal models such as Wang-Sheeley-Arge (WSA) and Magnetohydrodynamic Around a Sphere (MAS). A current magnetogram can be found here

http://iswa.ccmc.gsfc.nasa.gov:8080/IswaSystemWebApp/index.jsp?i_1=35&l_1=533&t_1=269&w_1=729&h_1=588&s_1=0_0_10_3&i_2=341&l_2=36&t_2=293&w_2=500&h_2=510&s_2=0_0_10_3&i_3=353&l_3=17&t_3=317&w_3=500&h_3=510&s_3=0_0_10_3

The right hand image on the above link is a magnetogram synoptic map. It can be thought of as a projection of the solar surface onto a flat plane. All of the magnetogram synoptic maps are compiled from solar magnetograms such as those taken from the GONG network magnetogram like the ones above on the left. To construct these synoptic maps only the central portion of the magnetogram image is used. A series of such images are taken as the sun rotates and are pasted together to construct a map over the course of a rotation. Some weighted averaging is done for areas that overlap.

Answer the following questions in your lab note book.

For the Synoptic Map, look at the axes on all sides. Notice that the left/right and top/bottom label pairs are different from each other. How do you interpret all the axes labels?
Why might the data near the poles be suspect?
There are two sets of dates at the top? What do you think these dates mean? (Notice the date on the raw magnetogram on the left. Also notice the direction that dates proceed on the synoptic map.)
Which region of the raw magnetogram corresponds to the active region labeled on the synoptic map? (Hint: Check the dates.)
Do the structures of the magnetogram and the synoptic map match exactly? If not, why not?

Solar Activity

Part 2: Observations

Introduction

In this lab you will explore structure of the solar magnetic field using visualizations of simulation results. After this lab you should:

- understand the structure of magnetic fields around active regions
- identify the origins of open and closed field lines
- compare the structure of the solar magnetic field at solar minimum and solar maximum

Getting Started

Open the "Space Weather Explorer" (SWX) which has a link on the desktop. Use the File selector to navigate to the "Solar" directory. Open the "mas_cr2080.cdf" file. The simulation results in this file were generated using the MAS ("Magnetohydrodynamics around A Sphere", insert links) model for Carrington Rotation (CR) 2080 near Solar Minimum in December of 2008.

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- Click the "+" button to add a surface.
- Click the "tool" button to open the surface settings. The "R" component should be set with the "constant value" near "1"
- Choose the "B_r" variable to display on this surface. "B_r" is the radial component of the magnet which is very near that which is extrapolated from the solar magnetograms. Click "ok".

The image should be very close to the synoptic map of the magnetogram synoptic map below and depicts the magnetic field near the surface of the Sun. For this model, the magnetograph synoptic map sets the inner boundary condition
You can compare it to the SOHO synoptic magnetogram at
http://soi.stanford.edu/magnetic/synoptic/carrot/M/2080/synop_Ml_0.2080.gif

Exploring the Solar Corona Solar Minimum

- In the "View" menu, click on "3D View" to see this image wrapped onto a sphere representing the solar surface magnetic field.
- You can rotate the image by using "click in drag" and zoom out using the mouse wheel.

1. **What general conclusions can you draw about the magnetic field at the surface of the sun during Solar Minimum? Is there a magnetic active region?**

2. **Draw what you think the solar magnetic field should look like in this case, and discuss it with your group.**
3. **What is the configuration of the field near the poles?**
4. **... near the active regions?**

You can choose some field lines by clicking on the solar surface in the original window.

- Start by clicking on field lines near the active region.

1. **What is the configuration of those lines? Do all the lines do the same thing?**

- Click on lines near the poles.

1. **What is the configuration fore these lines?How does this compare to you predictions above?**
2. **For field lines that begin and end on the surface of the sun, what can you say about the relative polarity of the foot points?**
3. **Approximately, what is the furthest extent that closed field lines extend out from the Sun?**

Clicking on the map provides seed points from which field lines are drawn. We can also import set of seed points from a text file. To explore the magnetic field more carefully, we can import a "regular" set of seed points.

- From the "View" menu, click on "Seed Points".
- To remove the points you have chosen click on "Remove all"
- Click the "Import" button and navigate to the "Solar" directory. The .csv files in this directory are text files with regularly spaced seed points. Choose "Global-1.5Rs.csv" to plot seed points starting at 1.5 solar radii. Click "ok" and hit the "Go" button on the 2D map. You may have to reopen the 3D view to see the field lines.
  - **What generalizations can you make about the origin of "open" and "closed" field lines?**
  - **Where do most of the field lines that reach the boundary originate from?**
  - **Where do most of the "closed field lines" originate from?**

Solar Maximum (Homework)

The example we will use for solar maximum is from CR 1965 which occurred during the last solar maximum, July of 2000.

- Use the "File" menu to navigate to the "mas_cr1960.cdf" file in the Solar directory.
- IncluClear the seed positions.
  - **What do you notice about the number and position of the magnetic active regions?**
  - **Draw what you think the solar magnetic field might look like for this CR.**
- Click on a few points on the map and explore the magnetic field structure.
  - **What conclusions can you draw about the structure of the closed field lines? Is it a regular structure? Do closed field lines only connect from one pole of an active region to the other pole of the same active region?**
  - **What about open field lines? Where do they originate?**
- Confirm your conclusions by using the regular seed points at 1.5 Rs and 28 Rs

Conclusion

Open field lines that reach out into the heliosphere tend to originate from coronal holes where much of the solar wind originates.

- **What conclusions can you draw about the source of the solar wind at solar minimum and solar maximum? At what latitudes does the solar wind originate from on the Sun?**

- Return to the iSWA window.
  http://iswa.ccmc.gsfc.nasa.gov:8080/IswaSystemWebApp/index.jsp?i_1=71&l_1=419&t_1=269&w_1=451&h_1=373&i_2=5&l_2=662&t_2=633&w_2=395&h_2=427&i_3=4&l_3=218&t_3=644&w_3=417&h_3=428&i_4=137&l_4=15&t_4=253&w_4=388&h_4=400&i_5=139&l_5=907&t_5=261&w_5=399&h_5=409
- Choose a date near the Solar minimum case above near December of 2008. Notice the model output in the middle of the screen. This model is the (PSFF) model.
  - **Are the field lines shown here consistent with what you saw in the MAS model?**
  - **What conclusions can you draw about the relationship between the "coronal holes" seen in the SOHO EIT (Extreme Ultraviolet Images).**