Tracking a Solar Storm: An Expert-Jigsaw Analysis

One way to describe a solar storm is to follow how it evolves in the different domains of the space environment, and how each domain effects the other domains in the system. These domains are broadly divided into four main categories: the solar corona, solar wind/heliosphere, magnetosphere, and ionosphere. In this each member of your group will become an "expert" in one of these domains, and then you will come back to the group and put the pieces of the "puzzle" together.

Audience: advanced undergraduates or graduate students in a specialized course on space physics.

Goals:
• broad overview of the space weather system
• explore the various data sets and simulation results available in a particular domain
• understanding how the space physics community organizes itself into specialized domains
• practice in working with others across domains to develop a systems view of the event

During this activity you will track a space weather event that occurred in July of 2017 between the 13th and the 20th. The links below are different "layouts" that use the iSWA (Integrated Space Weather Awareness, http://iswa.ccmc.gsfc.nasa.gov) web application. Each layout shows the observations and simulation results for a specific space environment domain (solar, solar wind, earth magnetosphere, and ionosphere) as it is impacted by the event. These layouts include: a solar photosphere and near corona, the solar corona, observations and model results for the solar wind model near Earth, model results and observations showing geomagnetic effects, and observations and models for the ionosphere.

Use the layouts, along with the wiki help pages (https://ccmc.gsfc.nasa.gov/support/ILWS/MATERIALS/iswa_wiki/index.php/Full_iSWA_Cygnet_List.html) and the glossary page (https://ccmc.gsfc.nasa.gov/RoR_WWW/presentations/Glossary_of_Space_Weather_terms.pdf) to answer the questions associated with each layout. These resources are incomplete so you may need do a little bit of detective work to understand what you are looking at.

Expert Groups

Divide up into "Expert Groups" to analyze one of the layouts.

Each “Expert Group” will analyze one layout. For each cygnet in the layout use the Wiki and Glossary entries above to answer the following questions.

- Does the cygnet show observational data or simulation results?
- If it is data, how is it collected? What spacecraft or ground station was used? What kind of instrument is collecting it?
- If it is simulation results, what model was used? What are the inputs to the model?
- What is the axes plotted? What is the scale? Does the scale change if you are looking at multiple time steps?
- What is this data used for? How do you interpret the data shown in the cygnet?
- What other data might you like to see that is not available but you think would be helpful?
- What predictions can you make about what the other expert groups will see?

Solar Surface and Coronagraphs
Solar Chromosphere: http://bit.ly/Solar_Corona_March2017
SOHO Coronagraphs: http://bit.ly/Coronagraphs_July2017

1) Do all sunspots have active regions associated with them?
2) Are all active regions associated with sunspots?
3) How would you define an solar active region? What characteristics does it have?
4) When does a solar flare occur? What criteria do you use to define the solar flare event?
5) Is there more than one event?
6) When does the CME (Coronal Mass Ejection) first appear in these images? Are the images consistent from one to the other?
7) Are all the solar flares associated with a CME?
8) Is the CME Earth bound? How can you tell? (You will want to check the position of the STEREO space craft https://stereo-ssc.nascom.nasa.gov/cgi-bin/make_where_gif)
9) What else can you learn or explain from this data?

Solar Wind
ACE & DSCOVR Data: http://bit.ly/Solar_Wind_Data_July2017V2
Solar Wind Models: http://bit.ly/Solar_Wind_Models_July2017

1) Is there evidence for a CME or a CIR in this data?
2) In terms of the solar wind plasma parameters, what are the signatures of the passage of a CME (Coronal Mass Ejection)? Note the date and time.
3) Based on the model results describe the global shape of the CME? How does this change the global magnetic field structure of the Heliosphere?
4) Based on the model results, roughly what solar angle of the heliosphere is affected by the CME?

5) Compare the model results timeline plot of the density and velocity to the ACE measurements of the solar wind. What does the model get right? Where are the model and the data inconsistent? Which do you trust more?
6) What does the GOES Proton data indicate?

Magnetosphere

GOES Data: http://bit.ly/GOES_MAG_July2017

- Top two panels show the Global KP derived from ground magnetometers and the magnetic field measured by one of the GOES satellites in geosynchronous orbit.
- The bottom two panels show the energetic protons and electrons respectively.

1) Identify the quiet time and disturbed time in this data.
2) Based on this data, how many CME's do you think impacted the magnetosphere? What are the indicators?
3) What drives the high energy electron flux?
4) What drives the high energy proton flux? (Included in the solar wind data)

Models: http://bit.ly/Magneto_Models_July2017

- The top panel shows the global magnetosphere simulation painted with plasma density. Selected field lines are traced throughout the magnetosphere. Note that these are projections of 3-D field lines so they may appear to cross but do not.
- The lower left panel shows a close-up of a similar simulation painted with magnetosphere current. The white line indicates the location of the magnetopause.

5) What are the indicators in the model results of the passage of the CME?
6) What are the effects on the magnetosphere?
7) Why might spacecraft in geosynchronous orbit be affected?
8) Is there any reason to question what the simulation is telling you?

Ionosphere:

Models: http://bit.ly/Ionosphere_July2017
Auroral Images: http://spaceweathergallery.com/index.php?&starting_point=100

1) Do you see significant changes in the structure of the ionosphere as shown by these results? Describe these and identify the onset time for the changes.
7) Does the structure of the ionosphere change significantly? ***(Pay careful attention to the color scales for the animation. Are they fixed or do they change?)***
8) Can you interpret parameters plotted? What do they represent? What could cause these changes and what effects might you expect there to be?
9) What conclusions can you draw from the auroral images submitted by users on the images page? What do you have to be careful about when using those images?

Jigsaw Groups

Your jigsaw groups are now made up of one person from each of the expert groups.

- Each expert should explain their findings to the rest of the group.
- ***How do the findings of each expert group relate to each other?***
- Devise a way to organize your findings and present it to the other groups. You may try one of the following:
  - Time Line
  - Event Concept Map
  - Summary of Storm Impacts
  - Some other approach?
- ***Consider the following questions as you organize the data:***
  - ***What are the initiators of the event? Which data sources indicate those***
  - ***What are the impacts of the event? Which data sources indicate those impacts?***
  - ***How do the initiators connect to the impacts?***