Assignement Answers
DAY 1 Tuesday 6/7

Assignment - Introduction to Space Weather

1. What is plasma?
Fourth state of matter, an ionized gas consisting mostly of charged particles, electrons and positive ions.

2. What is the fundamental feature of plasma?
Electromagnetic field plays a central role

3. Give an example of plasma environment:
For example solar corona, interplanetary medium, magnetosphere etc

4. How can you create plasma?
Heating, photo-ionization, charged particle bombardment

1. Which NOAA SWPC alert pertains to impacts caused by radiation belts?
GOES energetic electron alert

2. What NOAA SWPC alerts and reports information you think are useful for folks interested in spotting auroras?
For example, Kp index watched, alerts.

Assignment - Sun and its activity

1. What is plasma?
An ionized gas consisting mostly of charged particles, electrons and positive ions.

2. What is the solar wind?
The Sun constantly blows low density magnetized plasma from its outer atmosphere. This is called solar wind.

3. What is the Heliosphere?
The region of space dominated by the Sun. The edge of the heliosphere is a magnetic bubble-like medium and is located far beyond the orbit of Pluto.

4. What is a solar flare?
A sudden brightening observed over the Sun's surface or the solar limb, which is interpreted as a large energy release.

5. What is a coronal mass ejection?
An eruption of a huge mass of solar plasma from the solar atmosphere occurring from time to time http://iswa3.ccmc.gsfc.nasa.gov/wiki/index.php/Glossary
6. What is a sunspot and what properties does it have?
Sunspots look darker in the visible part of the spectrum on solar surface. They are caused by intense magnetic field, which inhibits convection, leaving their temperature (~ 3000–4500 K) lower than the temperature of surrounding material (~ 6000) K and makes them visible as dark spots. Sunspot sizes vary from 16 km to 160,000 km in diameter. Sunspots host coronal loops (http://iswa3.ccmc.gsfc.nasa.gov/wiki/index.php/Glossary) and magnetic reconnection events (http://iswa3.ccmc.gsfc.nasa.gov/wiki/index.php/Glossary).

7. What is an active region?
An active region on the Sun is an area with an especially strong magnetic field. Sunspots frequently form in active regions. They appear bright in X-ray and UV images. Solar flares and CMEs are often associated with active regions.

8. Core:
Region lying between center of the Sun and 0.5 of it's radius: 0-0.25 Rs; The temperature T~15 MK; Nuclear fusion reaction happening all the time.

9. Radiation zone:
0.25-0.7Rs; T ~ 7-2 MK; region transparent for photons

10. Convective zone:
0.7 – 1.0 Rs; T is lower than in Radiation zone. Energy is transported outward mostly by convection.

11. Photosphere (solar surface):
Thickness ~100 km, T~ 6000 K, T of a sunspot (typical) ~ 4200 K

12. Chromosphere:
1.0Rs - 2000 km, T ~ 20,000 K

13. Transition region:
above 2000 km - no clear upper border, T ~ 20000K – 1-2 MK, below this region dominates gravity, above - dynamic forces of the solar atmosphere.

14. Corona:
above the transition region, T ~ 2 MK. Corona is Sun's outer atmosphere expanding into the heliosphere, the region influenced by the magnetized solar plasma.

15. The solar magnetic field:

The Sun is permeated by overall roughly dipole magnetic field, similar to the Earth. The dipole field is produced by a circular electric current flowing deep within the star. The current is produced by shear (stretching of material) between different parts of the Sun that rotate at different rates, and the fact that the Sun itself is a very good electrical conductor. Local magnetic field is believed to be generated at the base of the Convective zone. Fields are stressed and pushed to surface.

16. Describe the relation between the solar magnetic field and solar activity:
When the solar magnetic field changes its configuration in a constantly varying solar atmosphere, this leads to release of energy and accelerating of solar plasma, causing flares and CMEs. More active regions with strong magnetic field on the Sun means stronger solar activity, more flares and CMEs.

17. Describe the solar cycles:
Solar cycle is a large time scale variation of the solar activity. During the solar activity maximum there is a large number of sunspots and active regions and corresponding bright areas in the solar atmosphere all over the solar surface. During the solar activity minimum we have almost spotless photosphere and much darker atmosphere. The magnetic field is more regular and concentrated mostly in the poles during the minimum. The activity varies gradually between the solar maximum and minimum. The time period of a cycle is about 11 years.

Assignment - Flares, CMEs and their impacts

1. How are solar flares classified and describe each one of the classifications?
Flares are classified by the X-ray flux intensity in the 0.1 – 0.8 nm wavelength range. A strong flare usually manifests itself by a sudden jump of the X-ray intensity. Flares are classified according to their X-ray Flux intensity in the 0.1 – 0.8 nm wavelength range:

Flux[Wm^(-2)] > 10^(-4)	X - (eXtreme), strong
Flux[Wm^(-2)] > 10^(-5)	M – (Moderate)
Flux[Wm^(-2)] > 10^(-6)	C – (Common)
Flux[Wm^(-2)] > 10^(-7)	B – (Background)
Flux[Wm^(-2)] > 10^(-8)	A

2. What is the class of a flare if it's Flux is 2.5*10^(-4)? X2.5

3. What is the correlation between solar flares and solar activity? The flares happen more often during and close to the solar maximum, but strong X-class flares can occur any time sunspots are present.

4. What can be the space weather impact of a solar flare? The flares can cause radio blackout through changing the structures/composition of the ionosphere (sudden ionospheric disturbances) due to x ray and EUV emissions. Affect radio

communications, GPS, directly by its radio noises at different wavelengths. Contribute to solar energetic particles (SEP) - proton radiation, with damaging effects on satellite instruments.

5. What is a coronal mass ejection? An eruption of a huge mass of solar plasma from the solar atmosphere occurring from time to time. If CME is directed towards Earth, depending on it's speed and size, it can reach the Earth in 1-3 days. CMEs are usually causing the strongest geomagnetic storms. Statistics shows that during the solar activity maximum there are about 5 CMEs per day, and during the solar minimum few CMEs a week (the ratio is of the order of 10).
Most of the CMEs originate from active regions, areas with an especially strong magnetic field.

6. What is a filament eruption? Not all CMEs originate from the active regions. Filaments are formed in magnetic loops that hold relatively cool, dense gas suspended above the surface of the Sun. Magnetic instabilities cause filaments to raise and parts of it disconnect from the solar surface resulting into CMEs.

7. What is the typical CME mass and speed? Mass: ~1014kg; Speed: few hundred - 3000 km/s

8. What is the CME classification and scale? CMEs are classified based on frequency of detection and speed. CME classification SCORE system complements flare classes:
S-type - speed less then 500 km/s
C-type (common) - speed range 500-999 km/s
O-type (occasional) - speed range 1000-1999 km/s
R-type (rare) - speed range 2000-2999 km/s
ER-type (extremely rare) - speed more then 3000 km/s.

9. What can be the space weather impact of a CME? Contribute to solar energetic particle (SEP) radiation, result in a geomagnetic storm, result in electron radiation enhancement in the near-Earth space. This can affect spacecraft electronics, radio communications, navigation (GPS), power grids etc.

10. What is the physical mechanism behind the flares and CMEs? It is believed that the magnetic field can change its configuration in a constantly varying solar atmosphere and during this reconfiguration it releases energy accelerating solar plasma causing flares and CMEs. The scientists are still debating on the details of the mechanisms, but the fact that the magnetic field is involved somehow is accepted by everybody.

Assignment - Solar Energetic Particles (SEPs)

1. SEPs are a source of space radiation. What is another source? Extra credit: What is yet another source?   GCRs (galactic cosmic rays)

2. What physical quantity do we monitor for SEPs, and what are the units? (for STEREO A, B , and GOES)? energetic proton fluxes, at GOES, we use the integrated flux for >10 MeV or >100 MeV protons. At STEREO A, B (when real-time data were available), we use the 13-100 MeV proton flux; The unit for GOES is pfu = particle flux unit = 1/cm^2/steridian/sec. For STEREOs, the unit is pfu/MeV; pfu means particle flux unit

3. How long after a flare can we expect SEPs to arrive at Earth? What factors influence their arrival time? Magnetically connectivity means how an observational point in space/heliosphere connects magnetically to the solar surface. Usually we use the modeled magnetic field of the sun to trace an observational point back to the solar surface. The magnetic connectively is important for SEPs as particles gyrate around magnetic field lines. How an observational point or spacecraft magnetically connects to an active region/source region at the Sun can provide information when an active region on the run erupts, the chance of radiation storm impacts due to SEPs.

5. What are some potential impacts of SEPs? (name a few) Include on satellite, ISS, and airline passengers, and PCA phenomena

6. What contributes to SEP intensity observed at a particular location?
If there is a flare, both flare and CME contribute, if no flare, the main contributor is CME or CMEs

7. When an SEP is detected at a location that is not well-connected magnetically, what might be the reason? see #3. The magnetically connectivity can also be altered by a fast and wide CME. Due to existence of CMEs, magnetically connectivity can be broadened and established.

8. Write down the thresholds that we use for our space weather notifications.
At GOES, the >10 MeV proton flux exceeds 10 pfu; the >100 MeV proton flux exceeds 1 pfu
At STEREOs, the 13-100 MeV proton flux exceeds 0.1pfu/MeV

9. Were there significant flares on March 7, 2012?
Yes

10. Were there accompanying CMEs?
Yes

When did the GOES >10 MeV proton flux start to exceed the threshold 10 pfu?
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