Introduction

The solar wind is a stream of ionized solar plasma emanating from the solar atmosphere and fills the interplanetary space. It is a result of the enormous difference between the pressure in the solar corona and the interplanetary space. Embedded within the solar wind plasma is the interplanetary magnetic field (IMF). Table I shows the typical values of solar wind parameters observed[1].

Table I. Observed properties of solar wind near the Earth

Proton Density	7 cm^{-3}
Electron Density	7 cm^{-3}
Flow speed	450 km/s
Proton Temperature	1.2×10^{5} K
Electron Temperature	1.4×10^{5} K
Magnetic Field	7×10^{-9} T

Variations in the speed, density and temperature of the solar wind plasma is due to the changes at the solar surface, in the corona, where the solar wind is generated, and due to the variety of interactions between the stream of charged particles and plasma waves in the interplanetary space.

High speed solar winds are usually generated through coronal holes and coronal mass ejections. Coronal holes are most frequent during low solar activity where they often extend from high to low latitudes[2]. Trans-equatorial or low-latitude coronal holes are typically fast. Figure 1 shows some examples typical trans-equatorial, Earth-facing coronal hole as seen from SDO/AIA 193. On the other hand, solar wind is usually accelerated through the coronal mass ejections. Large CMEs can increase the speed of the solar wind to about 1000 km/s and carries higher density and hot plasma. These events occur most often during increased solar activity.

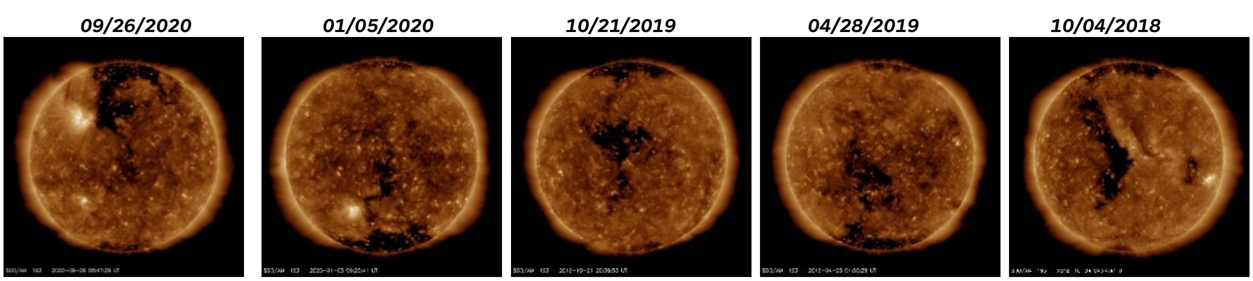

Figure 1. Examples of coronal holes.

There are two main spacecrafts that monitor the solar wind plasma properties, namely, the Advanced Composition Explorer (ACE)[3] and Deep Space Climate Observatory (DSCOVR)[4]. These spacecrafts are located at the L1 point near the Earth and monitors the solar wind magnetic field vector and plasma parameters such as proton density, speed, temperature, etc. Figure 2 shows an example of a 30-day data of the solar wind parameters (proton density, speed, and

[1] A.J. Hundhausen The Solar Wind (Introduction to Space Physics) Editors Margaret G. Kivelson and Christopher Russell Cambridge University Press Cambridge 1995

[2] Goldtsei, Melvin L. Solar Wind (Space Weather Fundamentals) editor George Khazanov CRC Press Florida 2016

[3] http://www.srl.caltech.edu/ACE/

[4] https://www.nesdis.noaa.gov/content/dscovr-deep-space-climate-observatory

temperature) taken from December 28, 2020 to January 27, 2021 by DSCOVR. From this figure, we can see that the density is of the order of 10 cm^{-3}, the speed varied from 300 km/s to 600 km/s, and the temperature ranged from 10^4 K to 10^6 K.

Figure 2. 30-day solar wind plasma parameter data from DSCOVR.

In this activity, you will determine the basic plasma parameters, such as Density, Speed, and Temperature, of the solar wind plasma as enhanced by a coronal mass ejection during the September 2017 X9.3 Solar Flare event.

Materials:

- Computer
- Internet
- Photo Editing software
- Word Processor Software
- Data Graphing Software

Instructions:

1. Go to NOAA Data Browser for DSCOVR: https://www.ngdc.noaa.gov/dscovr/data/
    a. Go to the directory of the desired date.
    b. Download the **`f1m`** file for September 6-9, 2017 to your desired directory
    c. Un-compress the files.
2. Install DSCOVR solar wind plasma data using the installer (read_solarwind_from_dscovr.exe) provided*. This was developed using MATLAB so for you might need an internet to install additional files.
3. Run DSCOVR Solar Wind Plasma Parameters reader.
4. Load and plot the data you downloaded. The program only reads one file at a time.
5. Plot (using other tools like *Python, MATLAB, Libre Office Calc, Microsoft Excel,* or *Apple Number, etc.*) the solar wind parameters for the whole duration. That is, one continuous plot showing the 4 days of observation.
6. Document your results in a word processor software (e.g., *Microsoft Word*, *Google Doc*, *Libre Office Writer*, *Apple Pages*, etc.)
7. Observe.

*Installer can be downloaded from https://macalalade.weebly.com/research.html

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CHALLENGE 1:

1. Search the internet for the 5 strongest CME events occurred in from 2015 to 2020.
2. Download 3 days before and after the event date. Here you will get a total of 7 days.
3. Plot each event separately and compare with each other.

CHALLENGE 2:

1. Go to *SpaceWeatherLive* Twitter account (**@_SpaceWeather_**).
2. Search its timeline for 3 trans-equatorial coronal hole events.
3. Download 5 the data from the date of the tweet and 5 days after the it. Here you will get a total of 6 days.
4. Plot each event separately and check when did the "enhanced solar wind" arrived and compare it from the expected arrival.

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