Properties of The Magnetosphere over the 11-year Solar Cycle

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Project for Dr. Nykyri's Space Weather (PS214) class

Abstract

The magnetosphere refers to the region encompassing a planet and its magnetic field. For Earth specifically, our magnetic field is shaped by the onslaught of streams of charged particles from the sun known as solar wind. Solar wind collides with the magnetic field of the earth and is deflected by it, deforming the magnetosphere in the process. As a result, the behavior of the magnetosphere changes with variations in the interplanetary magnetic field and solar activity. Understanding the behavior of the magnetosphere is crucial for accurate predictions of space weather storms and protecting earth-based systems such as satellites, airlines, and power grids. The purpose of this project is to study the properties of the solar wind at specific stages in the 11-year solar cycle in order to simulate changes in the magnetosphere resulting from fluctuating solar activity. By modeling the magnetosphere, we can better understand our planet's relationship with the sun as well as predict times of vulnerability to space weather.

Objective

To study how solar wind parameters change over the different stages of the solar cycle and how the magnetosphere changes in response.

Introduction

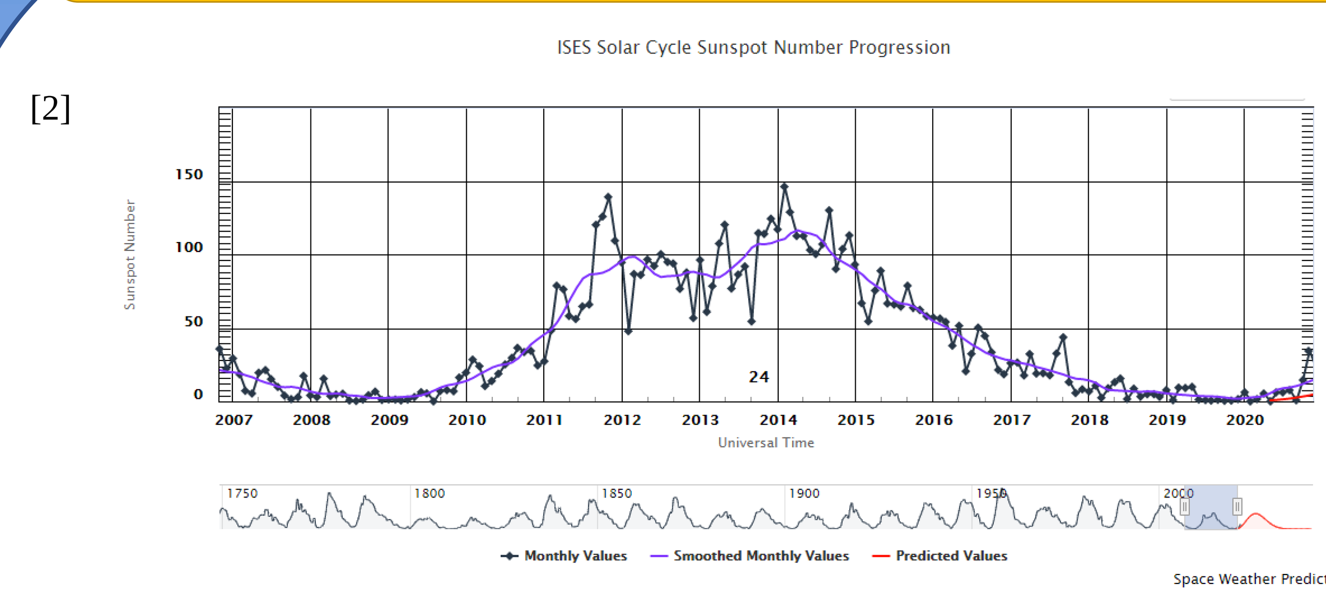
The earth's magnetosphere is the area around our planet encompassing our magnetic field and is shaped by the solar wind around it. The solar cycle describes how the solar activity of the sun changes based on the changes in the sun's magnetic field over an 11-year period and influences parameters of the solar wind such as its velocity, intensity of the magnetic field, density, temperature, etc. Every 11 years, the sun experiences a magnetic pole reversal. Over the course of the cycle, the solar cycle begins at a minimum level of solar activity known as the solar minimum. Here the average number of sunspots is at its lowest and solar wind is weakest. Then solar activity goes through a rising period in the cycle until it reaches the solar maximum at the peak of the cycle (approximately hallway through). Afterwards it declines until it reaches a solar minimum again, beginning the next cycle. The changes in solar wind over the sun's solar cycle leads to the changing of the magnetosphere over the solar cycle as well.

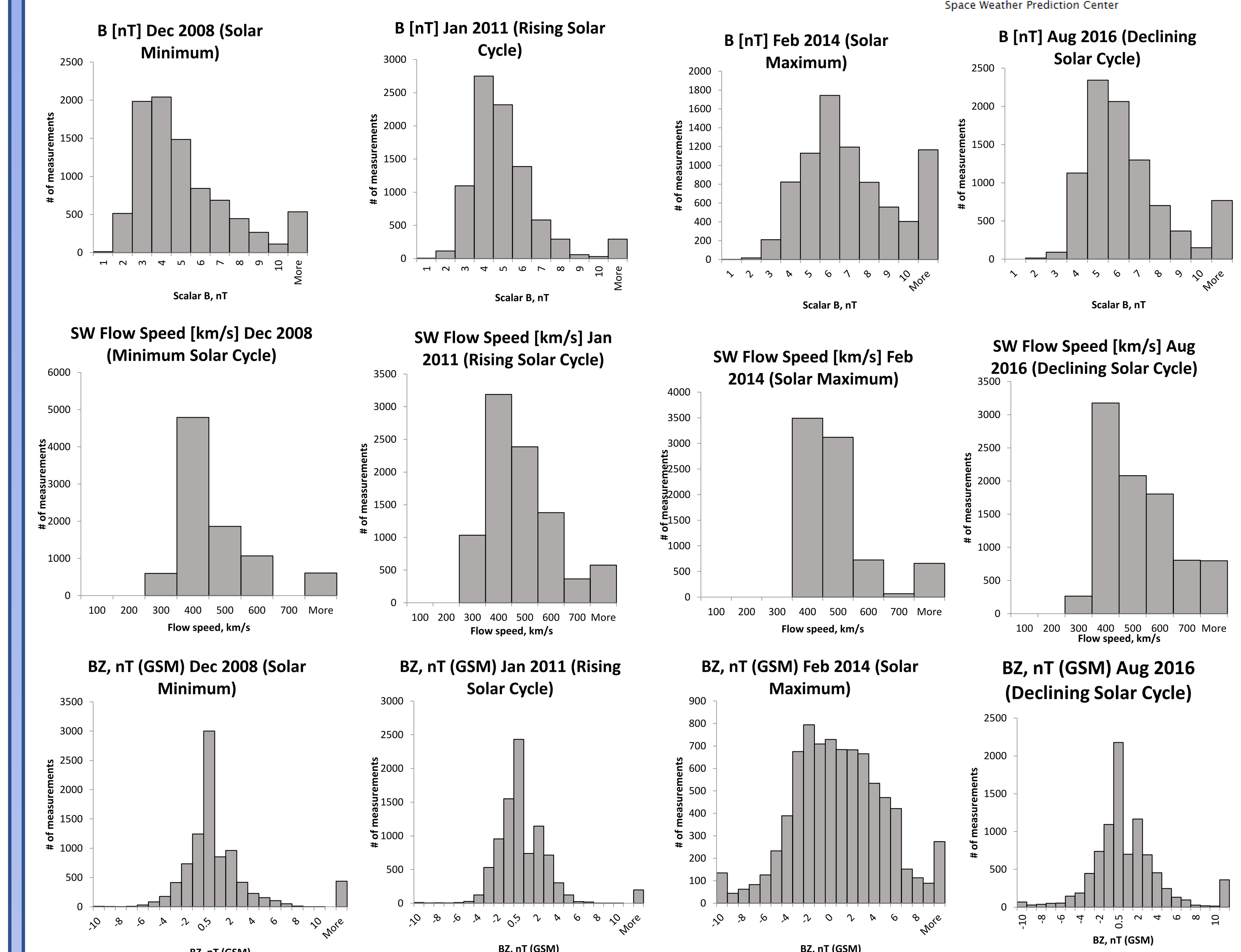
Methodology

In order to analyze the properties of the sun over the course of the solar cycle, periods of time representative of the solar minimum, rising solar cycle, solar maximum, and declining solar cycle were selected from one solar cycle. Solar cycle 24 is the most recently completed solar cycle, having ran from December 2008 until December 2019 [2] and was selected as the solar cycle of focus. Using NASA Goddard's OMNI Web online database [3], solar wind parameters were collected for one month that best represents each of the 4 periods in the solar cycle. Histograms for each month of data were created to analyze how solar wind parameters change throughout the solar cycle. From there, simulated magnetosphere models that best represented the average conditions during each period in the cycle were found using NASA's CCMC [1] and used as representative models to show how the magnetosphere changed in response to the variations in solar activity.

Solar Cycle Data

[2]

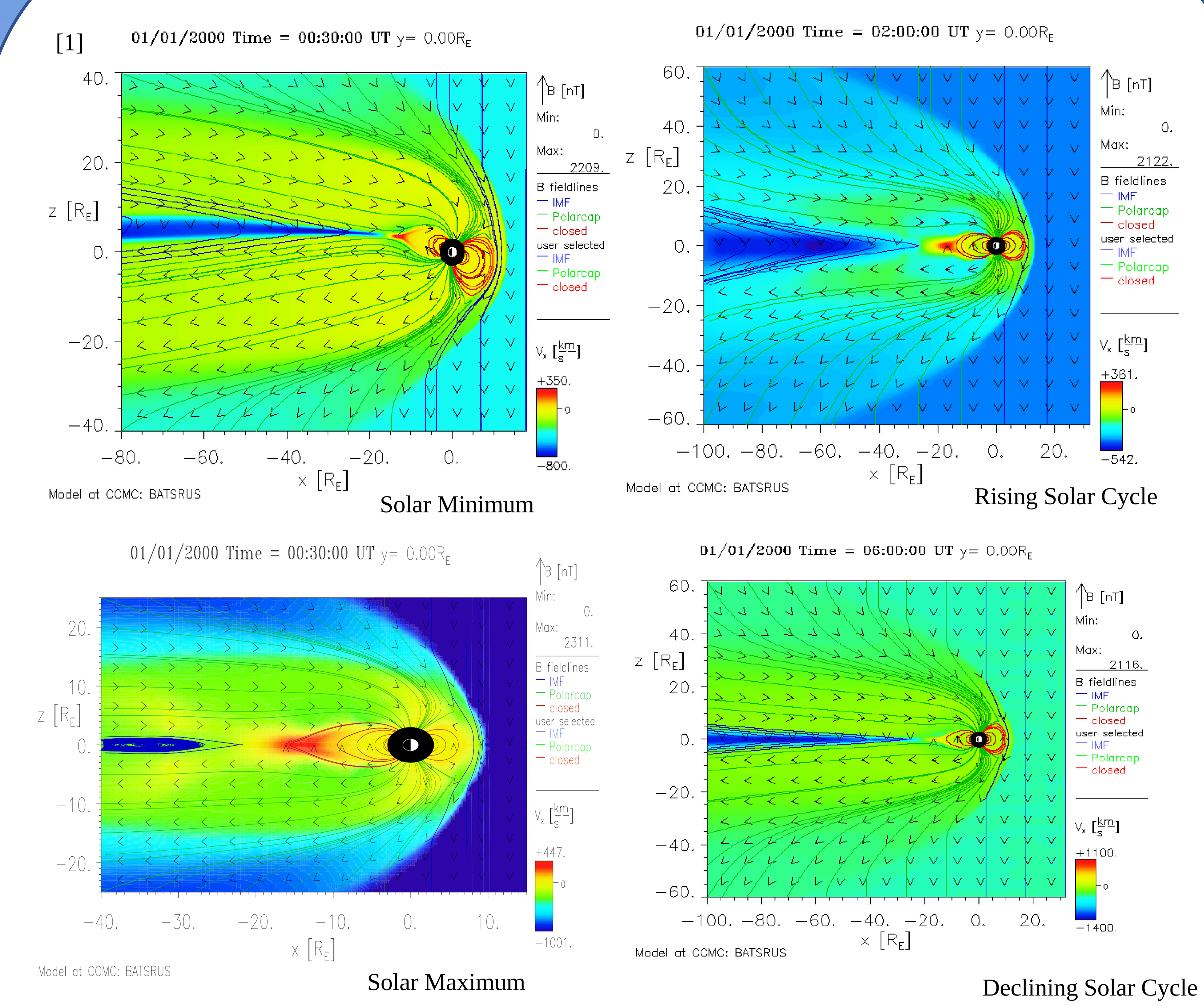




The first figure above shows the ISES Solar Cycle Sunspot Number progress over solar cycle 24 [2] and a smaller view of solar cycle 24 comparative to previous recorded solar cycles. The graphs underneath show histograms of one representative month for each stage in the solar cycle, created for the purpose of this project. The histograms each show the respective solar wind parameter and its frequency in the duration of each month. The months were choses based on the sunspot progression chart above. 3 of the 10 total solar wind parameters being observed are shown. As shown, especially in the Bz parameter, there are distinctive changes in solar wind in response to changes in solar activity.

Representative Magnetosphere Data

[1]



The four figures above are MHD simulations of the magnetosphere based on different input parameters. After analyzing the created histograms of solar wind data over the course of the solar cycle, the input solar wind in the simulations were chosen as being the closest representative to average solar wind parameters at each stage in the solar cycle. The solar minimum input parameters for Bz and Vx were -2 nT and -400 km/s Rising cycle input parameters were -5 nT and -400 km/s. Solar Maximum input parameters were -5 nT and 700 km/s. Declining cycle inputs were -4 nT and -400 km/s. By, Bx, Vy, Vz were all hekd constant at zero. All input parameters were held constant at zero. Input parameter decisions were limited by what already was available for use from CCMC as no new models were made.

Acknowledgements

[1] The MHD simulation results have been provided by the Community Coordinated Modeling Center at Goddard Space Flight Center through their public Runs on Request system (http://ccmc.gsfc.nasa.gov). The models used specifically were previously requested models in the database. The CCMC is a multiagency partnership between NASA, AFMC, AFOSR, AFRL, AFWA, NOAA, NSF, and ONR. The SWMF/BATSRUS Model was developed by Dr. Tamas Gombosi et al. at the Center for Space Environment Modeling at the University of Michigan.
[2] The Solar Cycle Sunspot Number Progression Plot was found at the NOAA Space Weather Prediction Center site at https://www.swpc.noaa.gov/products/solar-cycle-progression.
[3] The solar wind parameter data was extracted from NASA Goddard Space Flight Center OMNIWeb SDPF Online Data base at https://omniweb.gsfc.nasa.gov/ow_min.html
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