Examine the influence of internal structure of Coronal Mass Ejections (CMEs)

Abstract

The main purpose of this research is to determine the influence of internal structure of Coronal Mass Ejections (CMEs) on their propagation in the Heliosphere using WSA-ENLIL Cone Modeling. The Integrated Space Weather Analysis System and Stereo analysis tool was used to obtain several parameters: velocity, latitude, longitude, opening angle of the cone, and start time of CMEs that were used to examine the propagation time of Earth directed CMEs events. After getting these parameters for seven CMEs events, the ENLIL Cone Model was used to run five simulations for each event using different cavity parameters for the CMEs internal structure. The relationship between the cavity and CMEs propagation time and Kp index for several events was studied. As expected when the velocity of CMEs are higher than the solar wind speed heavier CMEs with smaller cavity propagate faster than the same size CMEs with larger cavity (lighter CMEs) was found. Quite naturally the opposite behavior is observed when the velocities of CMEs are less than the solar wind speed. For high CMEs velocities the Kp indices tend to decrease as the cavity increases while for slow CMEs velocities the Kp indices remain constant. The new version of the WSA-ENLIL code crashed for certain CME velocity and cavity parameter ranges. The problem was reported to the model developer and thus allows improvements to the model. This research is very important for improving model capability to forecast space weather.

Introduction

Coronal mass ejections (or CMEs) are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun over the course of several hours[1]. The most severe geomagnetic storms are caused by CME events. Kp indices provides a description of geomagnetic activity caused by solar particle radiation. This indices ranges from 0-9 and represents the measurements at a specific observatory[2]. CMEs can result in damage to satellites, disruption of radio transmissions, damage to electrical power transformers and power outages[3]. That is why knowing for example the arrival time of CMEs at the Earth accurately is of crucial importance in predicting space weather. For that reason this research presents the results of CME analysis tools and heliospheric simulations of figuring out optimal ways to forecast the arrival of CMEs at various orbits.

Materials/Tools

- MATLAB/Octave
- Integrated Space Weather Analysis System (ISWA)
- WSA-ENLIL cone modeling
- Terminal

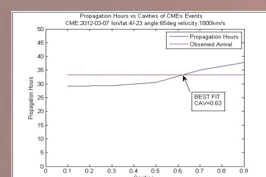
Results

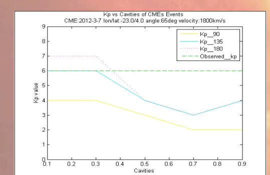
Fast CMEs

This column of graphs represents the behavior of the propagation hours versus cavity parameters of several CMEs events. The red line represents the observed time by the Advanced Composition Explorer (ACE) satellite.

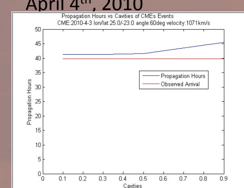
This column of graphs represents the behavior of the Kp indices versus cavity parameters of several CMEs events. The green line represents the observed Kp by different observatories around the World.

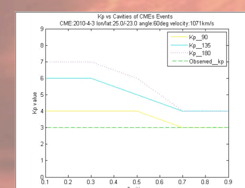
The first CME event analyzed was the one occurred on March 3rd, 2012





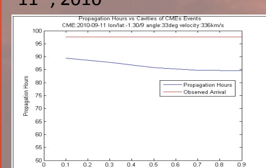
The second second CME event analyzed was the one occurred on April 4th, 2010

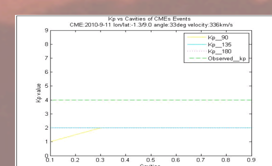




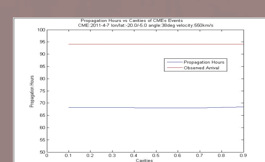
Slow CMEs

The third CME event analyzed was the one occurred on September 11th, 2010





The third CME event analyzed was the one occurred on April 4th, 2011



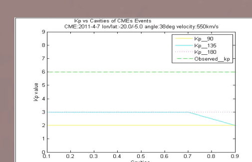
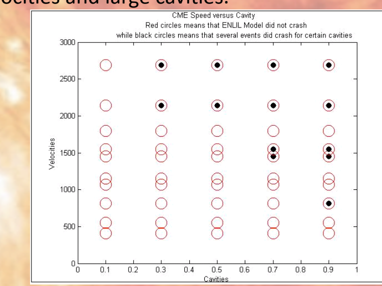


Diagram of ENLIL cone modeling: CME speed vs Cavity Radius

ENLIL cone model did not work (runs crashed) for high velocities and large cavities.



Conclusions

The results show that It easier to change the momentum of lighter (larger cavity) CMEs and thus lighter CMEs also adjust easier towards the background wind conditions: slow CMEs are picked up by the wind and fast CMEs are decelerated by the wind. There were used three different Kp indices for each event. For high CMEs velocities the Kp indices tend to decrease as the cavity increases while for slow CMEs velocities the Kp indices remain constant. The new version of the WSA-ENLIL code crashed for certain CME velocity and cavity parameter ranges. The problem was reported to the model developer and thus allows improvements to the model.

What's Next ?

A continuation to this work would be if there are more free parameters on the ENLIL Cone Model so that ones can see how these changes influence the propagation time of CMEs.

References

[1] Dr. Odstrcil. "Distortion of the Interplanetary Magnetic Field by Three-dimensional Propagation of Coronal Mass Ejections in a Structured Solar Wind." Geophysical Research 104 (1999): 225-28. Print.

[2] Taktakishvili, Aleksandre, Dr. Odstrcil, and P. MacNeice. "Model Uncertainties in Predictions of Arrival of Coronal Mass Ejections at Earth Orbit." Space Weather 8 (2010): 1-9. Print.

[3] Taktakishvili, Aleksandre, Masha Kuznetsova, and Antti Pulkinnen. "Validation of the Coronal Mass Ejection Predictions at the Earth Orbit Estimated by ENLIL Heliosphere Cone Model." Space Weather 7 (2009): 1-7. Print