Constraining CME Models using STEREO data for Space Weather Predictions

Syed Raza¹, Dr. Nikolai Pogorelov², Dr. Talwinder Singh²

1. University of Alabama, Birmingham, Department of Physics; 2. University of Alabama, Huntsville, Center For Space Plasma And Aeronomic Research

Abstract

In this work, we constrain the kinematics of our MHD coronal mass ejection (CME) model with multiple viewpoints of STEREO coronagraph and heliospheric imager (HI) data to improve the arrival time predictions. We show our approach using the 12 July 2012 CME. Using the kinematics derived from coronagraph observations and using the graduated cylindrical shell (GCS) model, we simulated a flux-rope-based CME. By comparing simulations and observations of this event at Earth, we found that our simulated CME arrived ~2.5 hours after the observed CME. To compare the evolution of our simulated CME with observations in the inner heliosphere, we created synthetic J-maps from our simulation data and compared them with the J-maps created from STEREO HI observations. By comparing the time-elongation angle graphs extracted from the synthetic and observed J-maps, we found that on average, our simulated CME was trailing the observed CME by 2 hours in both STEREO A and B. Offsetting this time from the arrival time of our simulated CME reduces the arrival time prediction error to just 0.5 hour. Therefore, constraining MHD models with HI observations has the potential to improve the arrival time predictions. This approach will be validated by performing simulations of multiple other CMEs as a future work.

Methods

A simulation of the 12th July, 2012 CME was developed by our team. The outer boundary of our domain was 1.5 AU. The domain was divided into small cells and MHD equations were solved in these cells. The inner boundary used was 12 Solar radii, and we used Sun’s magnetic field boundary conditions to start the movement of the CME. The figure on the right shows the propagation of simulated CME (Radial velocity) through our domain. The next objective in our work is to track the CME front through the field of view of HI2 on both STEREO A and STEREO B.

J-maps can be extremely helpful when calculating the time-elongation data of a CME. J-maps are basically made by taking slices of the ecliptic plane in time, which show the CME front moving through the interplanetary medium. We then put these slices in a vertical stack. We make the stack horizontal and plot. Physical time becomes the horizontal axis and the elongation angle of HI becomes the vertical axis. The diagrams on the right are the observed J-maps created from the field of view of HI aboard STEREO A and B respectively. Our goal is to make synthetic J-maps; the ones generated by looking at the density distribution as the simulated CME travels through the IP medium. Then we will extract time-elongation data from both observed and synthetic J-maps for comparison.

Results

We got concrete data from STEREO A. Above plots mean that the observed CME gets to a given angle before the simulated CME. That means that our simulation is trailing behind the observed CME by ~2 hours. STEREO B’s plot also agrees with this result.

Future Work

The next step is to use the computational approach in this study to analyze simulations of 6-7 more CMEs, and compare the arrival time with observations. We aim to publish our findings in a peer reviewed Journal.

Acknowledgements

This work was supported by funding from NSF grant AGS-1950831 for UAH CSPAR/NASA MSFC Heliophysics REU program. I would like to thank Rachel Ward Dr. Mehmet Sarp Yalın for organizing this REU, and my mentors Dr. Nikolai Pogorelov and Dr. Talwinder Singh for their attentive and skillful mentorship. Most of all, I am grateful to all the interns in this REU for making this experience extremely meaningful.

References