Automatic Detection of CME Leading Edges

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Background
A coronal mass ejection (CME) is a large magnetic plasma bubble that is ejected from the Sun over several hours. CMEs are the main cause of strong geomagnetic storms on Earth. The typical speed of CMEs is about 500 to 1000 km/s making their travel time to Earth anywhere between 1 and 5 days. It is important to study CMEs to help improve space weather forecasting tools.

The main part of our program is to automatically find the leading edge of a CME from the two different instrument images, SMEI and HI-2A. The leading edge of a CME is the outermost part of the CME coming off off the Sun. It is pointed out in the LASCO C2 coronagraph below.

Instruments

The Solar Mass Ejection Imager (SMEI) is aboard the Coriolis spacecraft in a polar orbit around Earth. SMEI scans the entire sky with three separate cameras to image a strip of sky that is roughly 180 degrees wide every 101 minutes. Creating a background subtracting image of the images taken by SMEI, it is possible to see CMEs coming off the Sun.

The Heliospheric Imager (HI) is aboard both of the STEREO spacecrafts, with one ahead of the Sun in its orbit (STEREO A) and one behind the Sun in its orbit (STEREO B). HI is a part of the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) suite. A new image is produced every 120 minutes by the STEREO HIs.

CLEDHI: CME Leading Edge Detection for HI

The CLEDHI program was written to automatically detect the leading edge of a CME when SMEI images are available. The program can distinguish noise regions by finding the leading edge of a CME.

CLEDHI Results

The program takes the CLED program and adapts it to read STEREO HI-2 images instead of SMEI images. After reading the HI images, it goes through the same steps as CLEDS and using the Hough Transform to pick out CMEs. CLEDHI has the ability to find the CMEs in the HI images. The noise regions are not necessary to find with the HI images because the images are a lot less noisy than the SMEI images. A typical STEREO HI-2A difference image is shown below from February 16, 2011 (Valentine’s Day Storm). A STEREO A EUV 195 image of the sun taken on February 15, 2011 1:55 UT shows the X-Class flare associated with the CME and roughly indicates where the Sun would be with respect to the HI images.

CMEs

Creating two programs to automatically detect the leading edge of a CME: CLEDS: CME Leading Edge Detection for SMEI

CLEDS Results

The program was first written to identify the entire CME and all of the noise in the SMEI image. The SMEI images are very noisy so it is important to distinguish noise regions because CMEs could be hiding behind the noise. The program was then edited to identify just the leading edge of the CME and just the edges of the noise gaps. The leading edge and noise gap information will then be sent off to become an input for the Tappin-Howard (TH) model to make a prediction about when the CME would impact Earth.

The Next Step: TH Model

After CLEDS and CLEDHI find the leading edge of the CME and the noise gaps, if needed, the results are contained in text files which are then fed to the TH model. The TH model compares the measured leading edge data with those from simulated CMEs to create an estimation of CME geometry and kinematics. With the CLEDS, CLEDHI, and TH model running with each new image becoming available, the TH model can make a new prediction of CME impact with Earth every two hours or so. This makes the model useful because it can keep refining its prediction increasing its accuracy of prediction each time and do so in an automated way.

A real time prediction for the February 2011 CME (Valentine’s Day Storm) performed by many models is shown below. The TH model predictions are labeled with TH. In general, the HI models did a better job predicting than the coronagraph models. This is because the heliospheric imagers can detect the CME acceleration or deceleration, while the coronagraphs cannot. This storm happened to decelerate on its way to Earth.

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