Space Weather Monitor at the L5 point: A Case Study of a CME Observed with STEREO-B

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1. STEREO Location During The Event

In October 2009, STEREO-B reached the L5 point behind the Earth in its orbit (Figure 1). On 2009-Oct-17 an Earth-directed partial-halo CME was observed by SOHO from the L1 perspective. Providing an opportunity to test the advantages of having a spacecraft located in this position to improve our space weather forecasting capabilities.

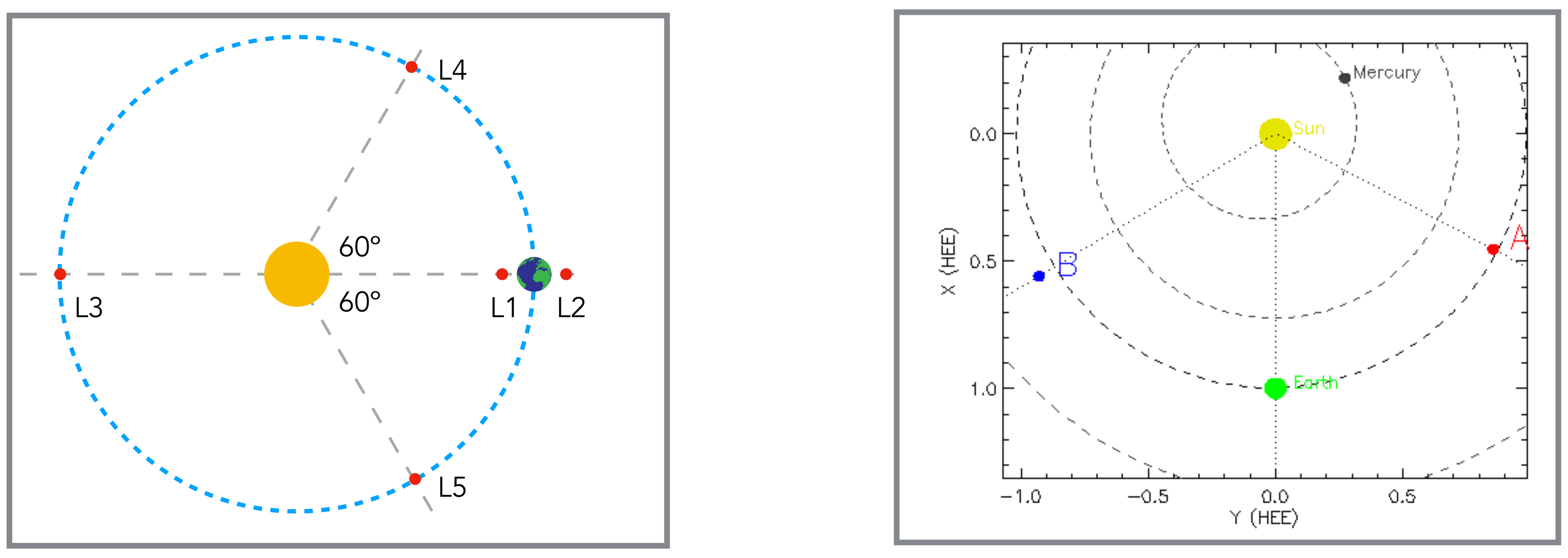


Figure 1. Left: location of the Lagrangian points of the Sun-Earth system. Right: positions of the STEREO-A and B spacecraft on 17 October, 2009. The angle between STEREO B and the Earth was 59° (source: STEREO Science Center).

3. Calculation of CME Speed

The CME speed was calculated using COR2, HI1 and HI2 (all on STEREO-B). Two methods were used:

•Feature tracking: A point belonging to the CME was tracked manually in HI images from 3 to 150 Rs (beyond this distance the CME becomes too faint).

•J-map tracking: A J-map at the required position angle is created and used for tracking.

The HI instruments provide us with a measurement of feature elongation from the Sun. In order to convert elongation into radial distance from the Sun we used the Fixed-Phi, Harmonic-Mean and Self-Similar-Expansion methods. The results are similar, and shown in Figure 4. The speed is calculated from the radial distance values.

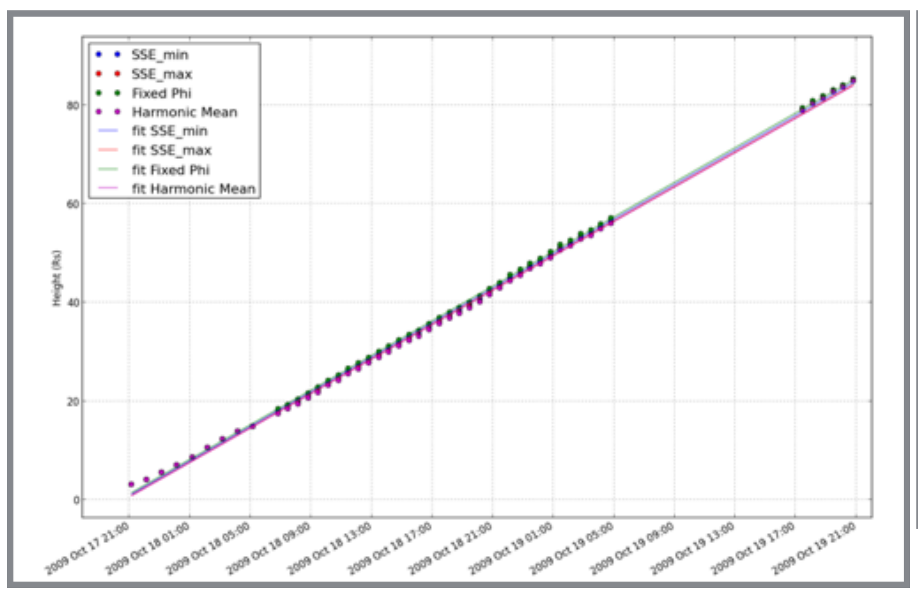


Figure 4. Height vs. time plot for the CME on October 17. Four different methods were used to convert from elongation to radial distance (in Rs), they give very similar results.

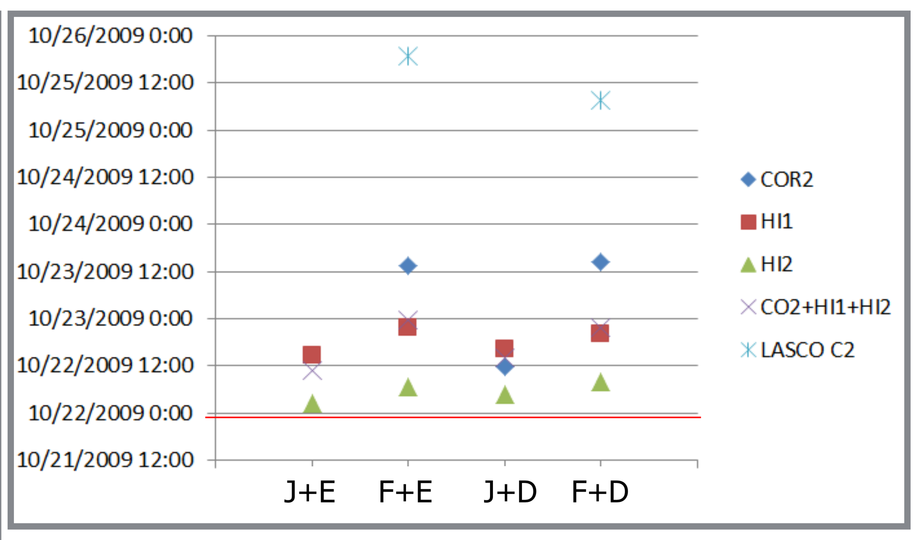


Figure 5. Arrival times using different methods applied to the observations provided by L1 (SOHO) and L5 (STEREO B) instruments. The red line marks the real arrival time of the shock at 1 AU. J stands for J-map tracking, F for Feature tracking, E for extrapolation and D for Drag Based Model.

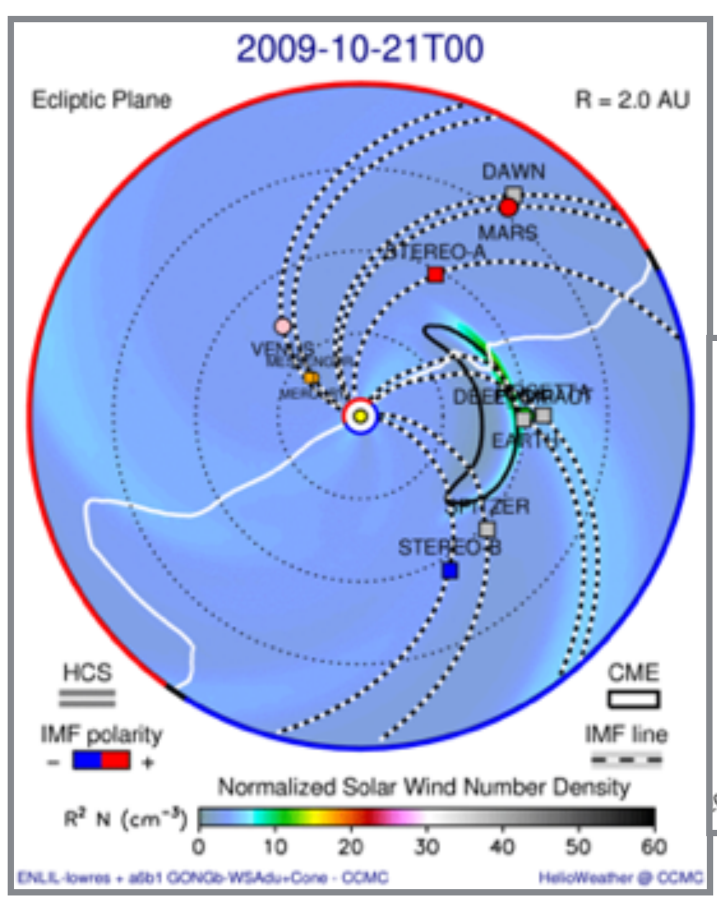
4. Calculation of CME Arrival Time

The arrival time was calculated with two methods:

•By applying a linear fit to the data and extrapolating the results to 1 AU.

•By applying the Drag-Based Model.

Results are shown in Figure 5. The CME (shock) arrived on 2009-Oct-21 at 23:25 UT. HI2 data produced the best result, independent of the method applied. With HI2 data combined with J-map tracking yielding an arrival time at 02:20 UT on Oct-22, three hours later than the real arrival time. The arrival times obtained with the L1 data (SOHO LASCO C2) are the farthest from the observed arrival time, arriving 4 days later than expected.



We have also applied ENLIL to the data, using a large variety of input parameters derived with various methods. These results (Figure 6) are only preliminary at present, the model predicts the CME arrival too early, possibly due to the background solar-wind speed being too high in the simulations.

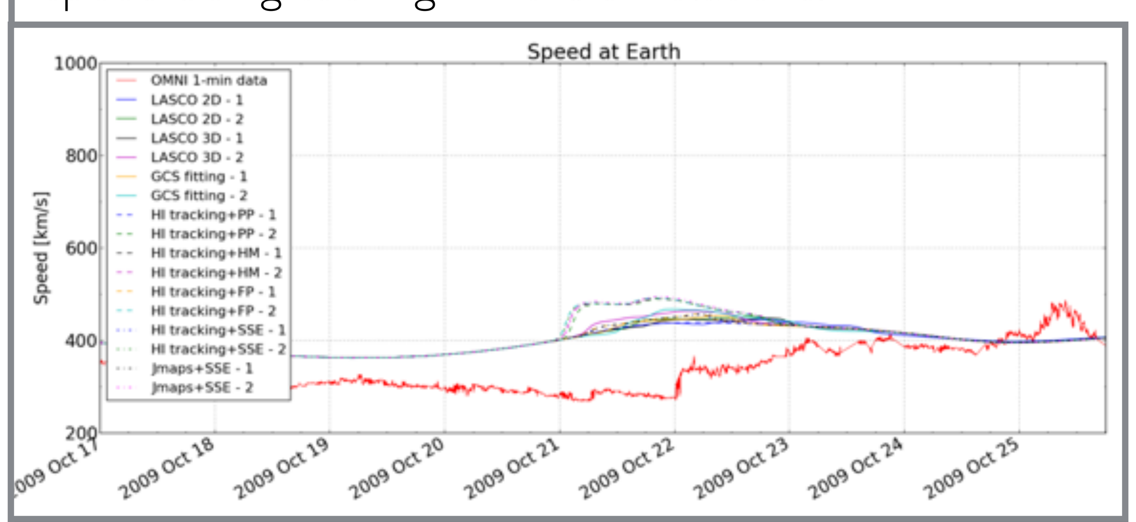


Figure 6. Preliminary ENLIL results showing the ICME arrival time on Oct-21.

2. The CME & ICME

The 2009-Oct-17 CME, shown in Figure 2, was seen from the perspective of the L1 point by the SOHO EIT EUV imager and LASCO-C2 coronagraph, and from the L5 perspective, by the STEREO-B SECCHI EUVI, COR2 coronagraph and HI telescopes.

The corresponding ICME arrived to the L1 point on 2009-Oct-21 as shown in Figure 3.

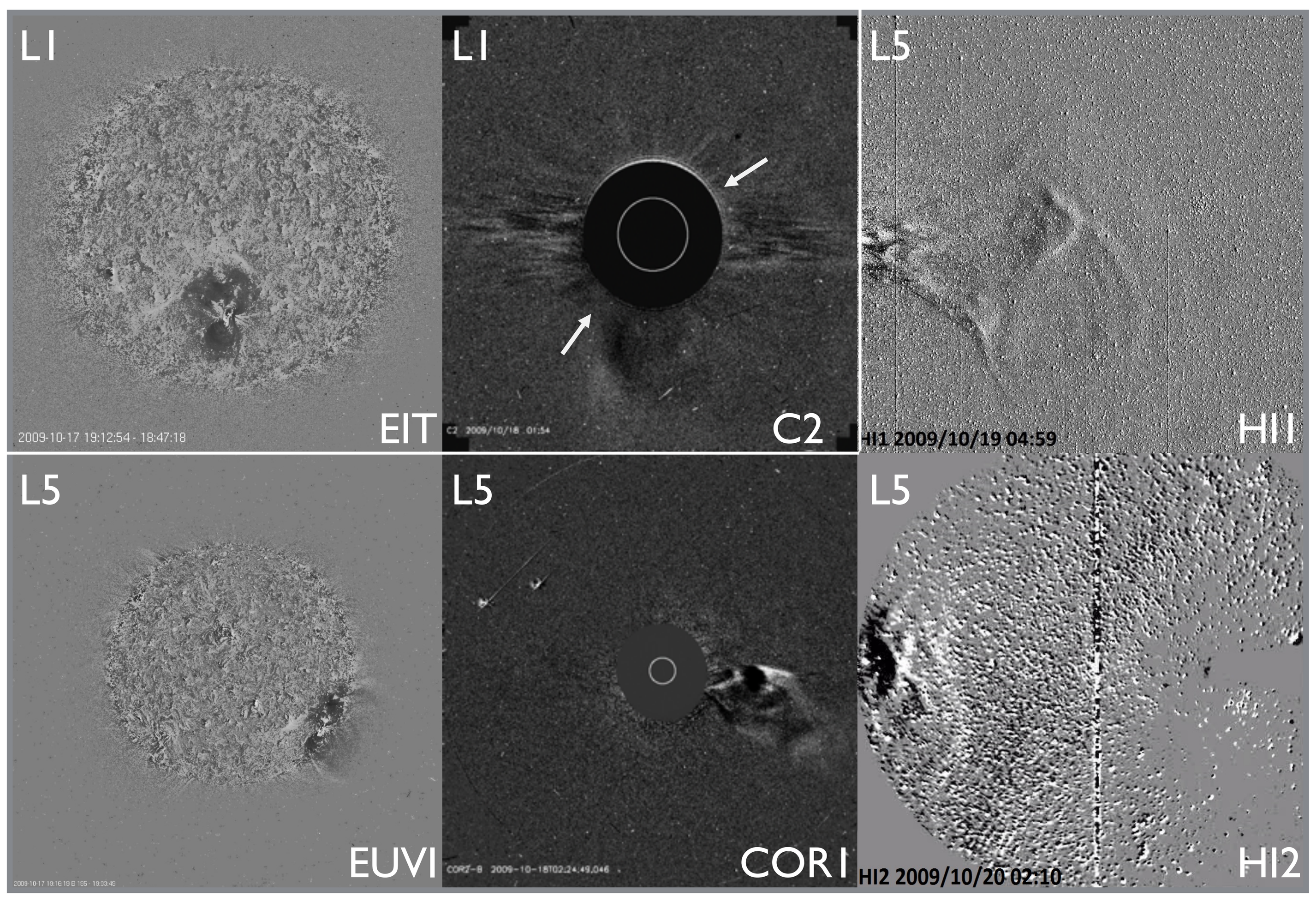


Figure 2. Running difference observations of the CME from 2009-Oct-17 from: EIT (Top-left), EUVI (Bottom-left), C2 (Top-middle), COR2 (Bottom-middle), HI1 (Top-right) and HI2 (Bottom-right). arrows in the top middle panel mark the angular extent of the CME in the C2 field of view. N.b. The Earth is located at the vertical stripe in the middle of the bottom-right panel.

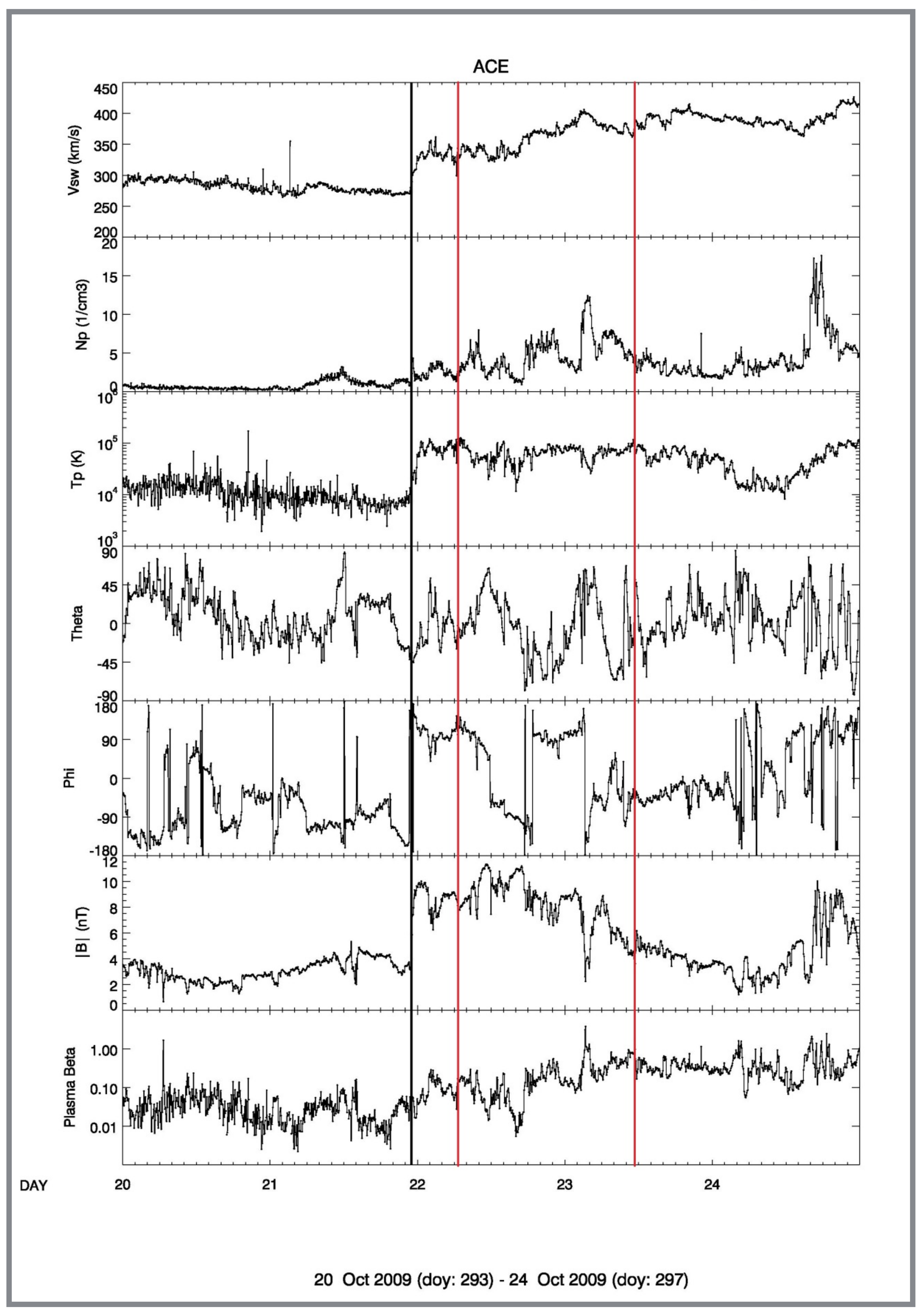


Figure 3. ACE plasma and magnetic field data showing the shock (black vertical line) and the driving ICME coming behind (between the red lines), on 2009-Oct-21/22. From top to bottom, the panels show: solar wind speed, proton number density, proton temperature, latitudinal and azimuthal angles of the interplanetary magnetic field vector, the interplanetary magnetic field intensity and the plasma beta.

5. Discussion of Operational CME Forecasts

The observation of the CME was announced on 2009-Oct-18 by the Solar Influences Data analysis Center (SIDC) at the Royal Observatory of Belgium and the Space Weather Prediction Center of the National Oceanic and Atmospheric Administration (NOAA). SIDC predicted an Earth arrival without further details, NOAA calculated the CME speed to be 230 km/s, based solely on LASCO observations. Neither NOAA or SIDC predicted any geoeffectiveness. On Oct-22 reports of the ICME arrival were issued by both centers. The ICME arrived at ACE (Figure 3) and then at the Earth, producing active geomagnetic conditions, with Kp=4 and local K-indices reaching K=6 at high latitudes. If the data from STEREO-B at the L5 point had been used, the forecast could have been improved. The CME observed by both COR2 and LASCO would have been classified undoubtedly as an Earth-directed CME, and its arrival time better calculated.

6. Summary of Operational CME Forecasts

•Having L5 data space-weather forecasting capabilities improved the accuracy of forecasts, especially when compared to having only L1 observations.
•Heliospheric imager data at L5 is of crucial importance. In this example, HI2 provided the best results (due to its FOV, allowing the tracking of the CME up to 150 Rs).
•Not only arrival times, but also CME direction and 3D structure are improved by L5 data.
•The ENLIL runs using different input parameters will be studied in detail in the future.