# PREDICTION OF CME ARRIVALS: DIFFERENCES BASED ON STEREOSCOPIC HELIOSPHERIC IMAGER DATA

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Coronal mass ejections (CMEs) are clouds of magnetized plasma with huge masses (up to $10^{13}$ kg) which are expelled from the solar corona. When directed towards Earth, CMEs can disrupt communication and navigation systems, damage satellites and even lead to power outages.

We present the results of a statistical study using the prediction model ELEvoHI[1] (ELlipse Evolution model based on Heliospheric Imager observations). The model uses time-elongation profiles (tracks) provided by HI (Heliospheric Imager) onboard STEREO. For each CME under study, we perform ELEvoHI ensemble modeling[2], which gives us a probability of an Earth arrival and a distribution of the arrival time and speed.

We compare our results to already existing ICME lists[3,4], show the differences in the predicted arrival times and speeds for the same CME using STEREO-A (STA) and STEREO-B (STB) HI tracks and discuss possible reasons based on an example CME occurring on the 30th of January 2011.

## DATA & METHODS

We analyze the model results obtained from ELEvoHI for 12 CMEs in the time range February 2010 to July 2012. During this period of time the two STEREO spacecraft exhibited a separation angle with respect to Earth ranging from about 65° (close to L4/5) to 120°. ELEvoHI assumes an elliptical shape of the CME front and that the drag force exerted by the ambient solar wind is the dominant force influencing the CME propagation in the interplanetary space. For this study, the ambient solar wind is provided by the Wang-Sheeley-Arge/ Heliospheric Upwind eXtrapolation (WSA/HUX) model combination[5]. The HI time-elongation tracks are converted to time-distance profiles which are used for DBM[6]-fitting to get an estimate of the drag parameter. The additional input parameters $\phi$ (propagation direction), $\lambda$ (half angle), and f (inverse ellipse aspect ratio) are obtained from an ecliptic cut of the graduated cylindrical shell (GCS[7,8]) fit and vary in ensemble mode: $\phi$: ±10° (2° steps); $\lambda$: ±10° (5° steps); f: 0.7-1.0 (0.1 steps). Fig. 1 shows the arrival times for one ensemble run.

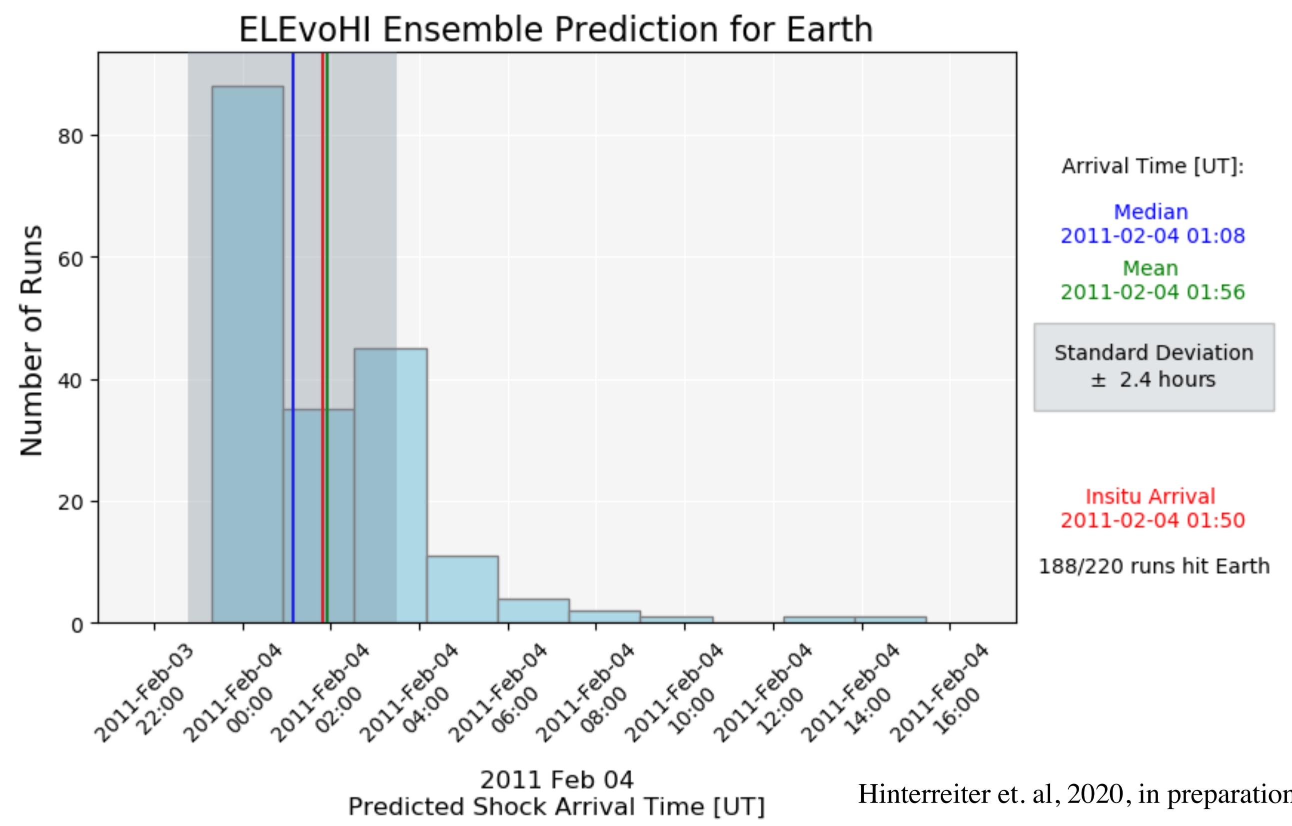


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Fig. 1: Distribution of the arrival times for the 20110130 event. The blue and green vertical bars represent the median and mean arrival time, respectively. The red vertical bar indicates the in-situ arrival time.

## ACKNOWLEDGMENTS

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## RESULTS

Fig. 2 shows the distributions of the arrival times and speeds for the 12 analyzed CMEs. According to the input parameters to ELEvoHI, we believe that two events (20100319, 20110906) can be considered as ‚flank hits', explaining the late arrivals. We find that the difference in the predicted mean arrival times can reach up to 10 hours based on STA and STB inputs. Fig. 3 shows two snapshots of the CME propagation movie for the CME on 30th January 2011. We indicate the region of the ellipse that is seen from the SC with a dot in the corresponding color (red, blue). This point represents the leading edge of the ellipse as seen from either STA or STB.

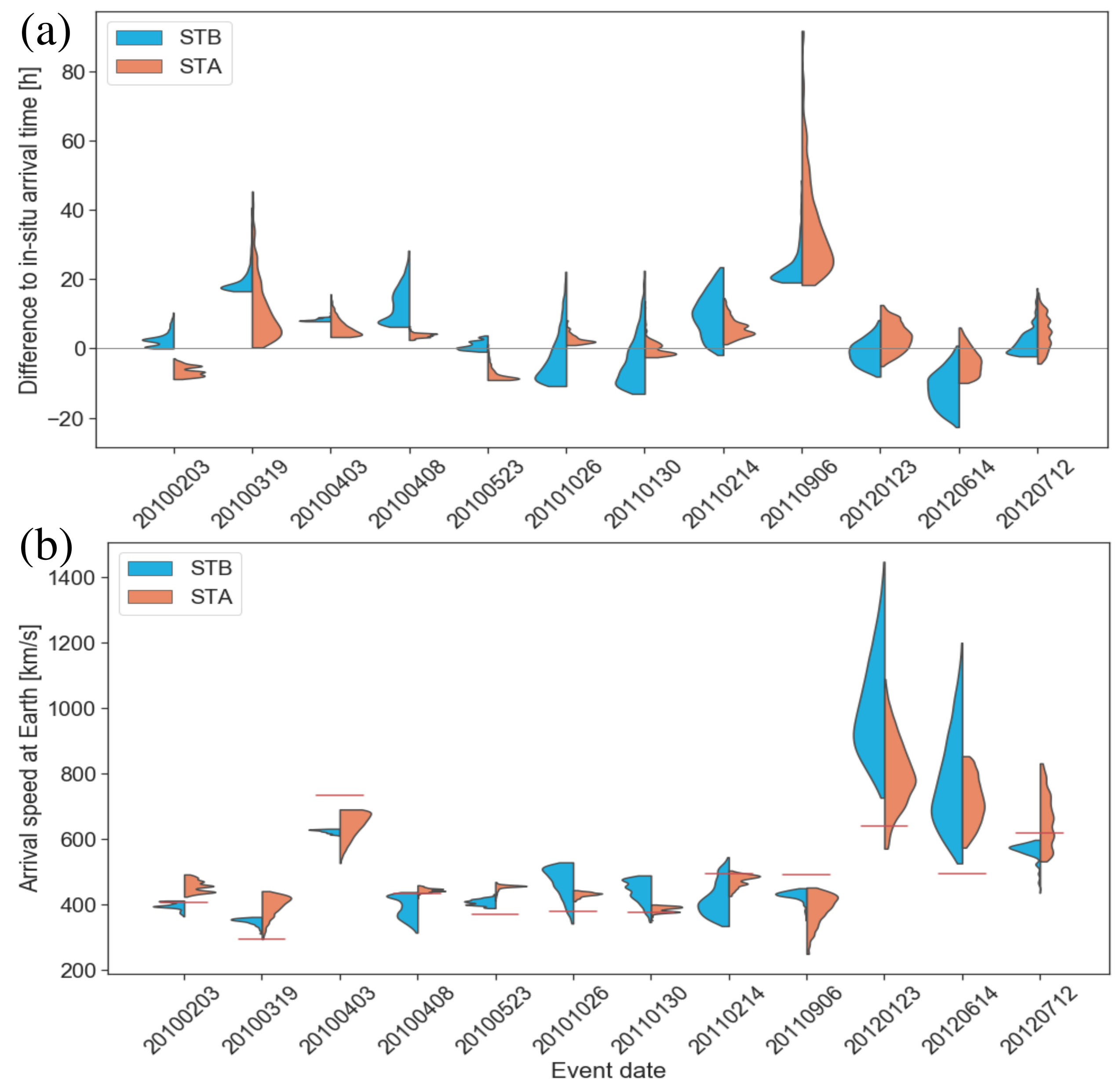


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Fig. 2: Violin-plots for the arrival time (a) and arrival speed (b). The distributions of the ensemble results for STB and STA are shown in blue and orange, respectively. In the top panel (a) the difference in the predicted arrival time with respect to the in-situ arrival time can be seen. The bottom panel (b) shows the distribution of the predicted arrival speeds, with the red vertical lines indicating the in-situ arrival speed.

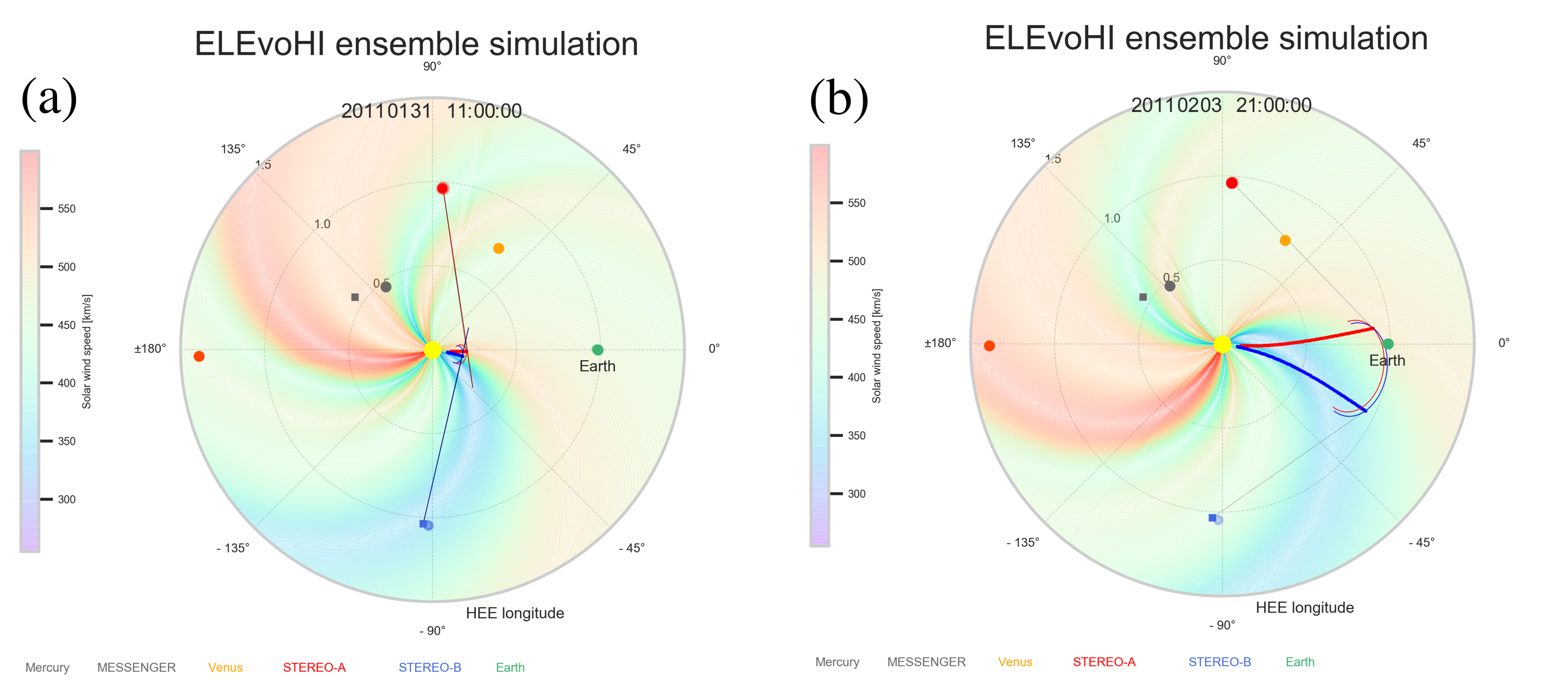


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Fig. 3: Snapshots of the CME propagation for one individual run based on STA (red) and STB (blue) inputs. The ambient solar wind is computed using the WSA/HUX model combination. The red and blue lines in the left panel (a) show the HI elongations tracked by the user. The dots in red and blue show the intercept of the idealized elliptical front of the CME and the tangent as seen from STA and STB, respectively. Link to the movie: https://figshare.com/articles/20110130_AB_ensemble_movie_mp4/12179919

Fig. 4 shows the elongation angle of the tangent point (colored dots in Fig. 3) seen from STA (a) and STB (b) and the ambient solar wind speed at this point. Here, we clearly see that the features tracked within HI-A and HI-B experience a different ambient solar wind speeds as the CME propagates and therefore the kinematics and the following arrival prediction derived from these tracks are likely to differ.

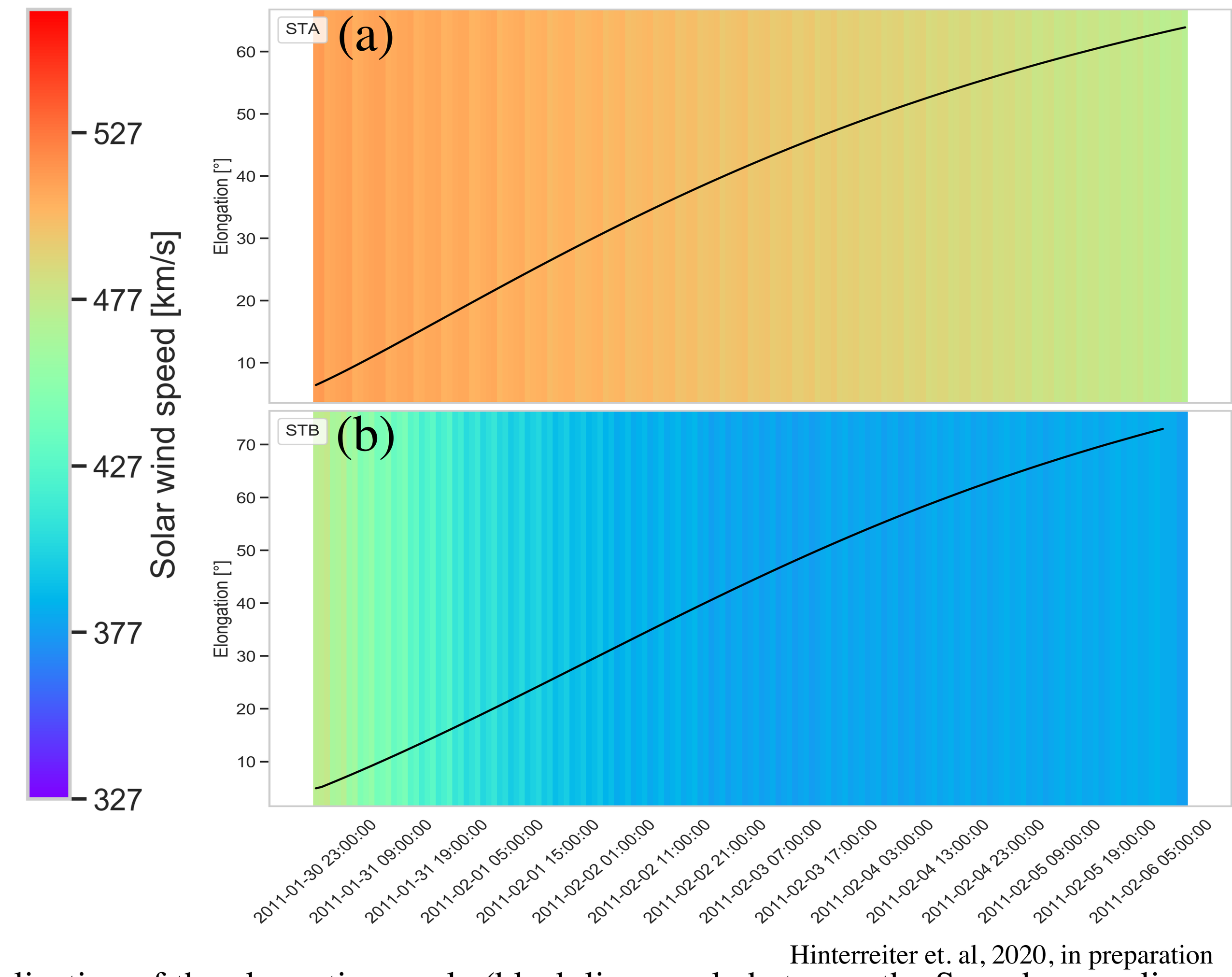


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Fig. 4: Visualization of the elongation angle (black line, angle between the Sun-observer line and the line of sight), seen from STA (a) and STB (b) and the speed of the ambient solar wind speed at the tangent point (red and blue dots in Fig. 3)

## DISCUSSION & CONCLUSION

We present the results from ELEvoHI ensemble modeling for 12 well observed CME from 2010 to 2012, seen by both STA and STB. We find that the difference in the predicted arrival times between STA and STB HI tracks for one CME can reach up to 10 hours. The reasons might be the following:

- Different parts of the leading edge (tangent point) of the CME are observed in STA and STB HI images (Fig. 3)
- The kinematics of the features tracked within HI do not necessarily correspond to the apex kinematics of the ellipse (Fig. 3)
- The tangent point experiences different ambient solar wind speeds seen from STA and STB (Fig. 4)
- The ambient solar wind speed at the tangent point is not constant during propagation (Fig. 4).

We expect improved model results after further development of ELEvoHI in such a way that the CME front is able to adjust its kinematics and frontal shape according to a structured ambient solar wind. We are convinced that combined HI observations from two vantage points leads to better forecasts. Therefore, we strongly support L1 and L5 satellite missions.

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