Systematic testing of different de-projection methods for STEREO imagery

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Introduction

Using single spacecraft measurements from STEREO-COR2+HI1+HI2 we study the propagation behavior of a sample of well observed coronal mass ejections (CMEs) in interplanetary space. For this we started to do a systematic testing on different de-projection methods for transforming off-pointed and wide field HI1/HI2 images to Sun centered polar coordinate system (NRL tool versus SATPLOT/JPL tool). First results for the ecliptic plane showed that both tools deliver reliable results for the measurement of elongation of CME structures.
The time-elongation measurements from NRL and SATPLOT (Solar Angle-Time Plot) are further used for deriving a CME arrival time at 1AU, by assuming constant CME speed and direction. For single spacecraft data we use several fitting methods, approximating the evolution of the CME front with different geometrical shapes (Fixed-Phi [Sheeley et al., 1999 JGR], Harmonic Mean - HM [Lugaz et al., 2009 AnGeo], Self-Similar Expansion - SSE [Davies et al.,2012 ApJ]). The results will give error estimation on forecasting of CMEs using the different methods.

De-projection methods

SATPLOT/JPL Tool

Using SATPLOT software, elongation versus time plots ('jplots') can be created and analyzed. The tool uses a library of cylindrical maps of the SECCHI data for each spacecraft's panoramic field-of-view prepared at JPL. The maps are created using a Plate Carree projection, optimized for creating the elongation versus time plots.
Developed by J.R. Hall, P.C. Liewer (NASA/JPL)

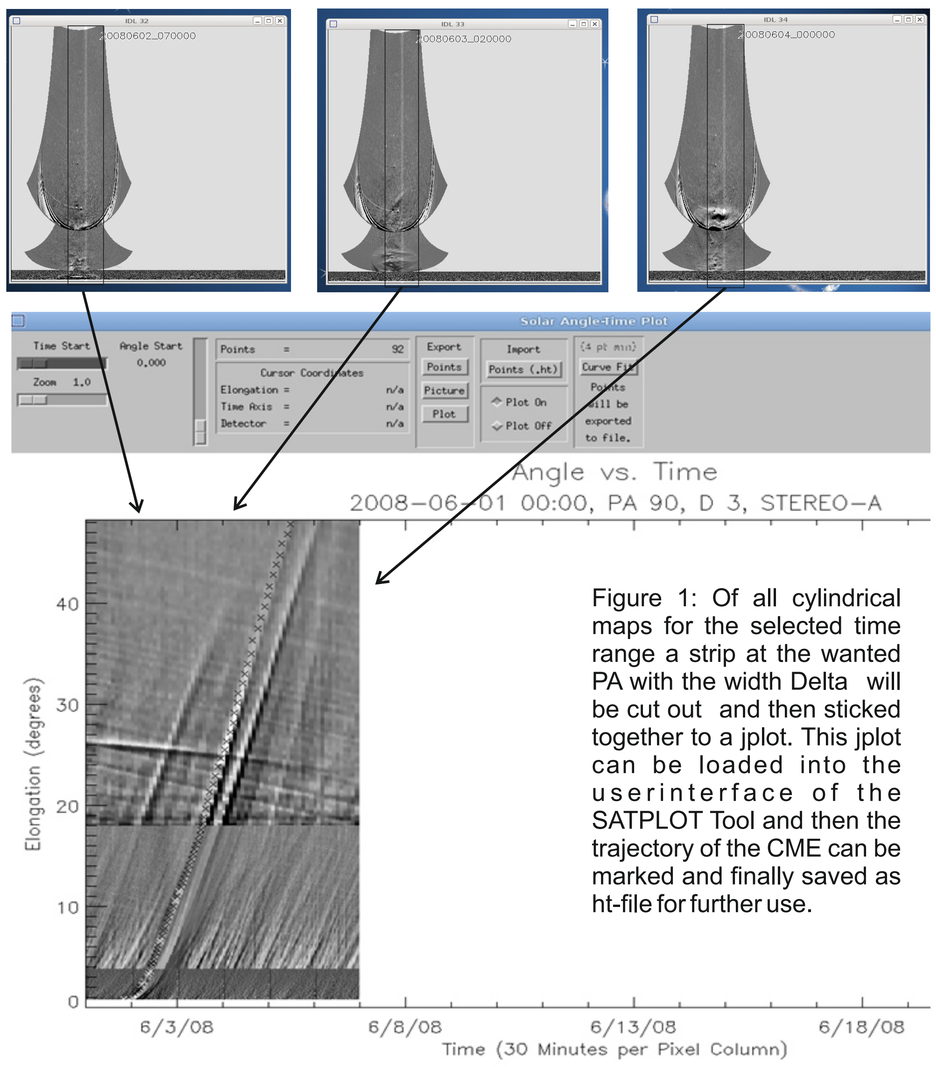
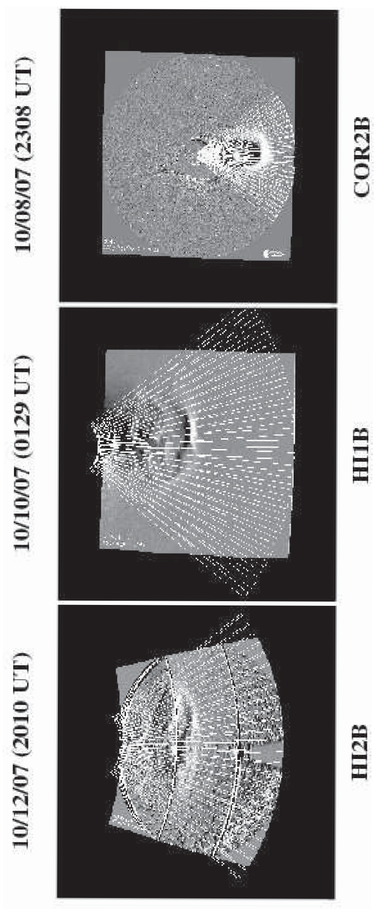


Figure 1: Of all cylindrical maps for the selected time range a strip at the wanted PA with the width Delta will be cut out and then sticked together to a jplot. This jplot can be loaded into the userinterface of the SATPLOT Tool and then the trajectory of the CME can be marked and finally saved as ht-file for further use.

NRL-Tool

The NRL-tool has the same purpose as SATPLOT, but is used with a different approach. Raw STEREO-data first need to be downloaded and prepared before working with the software. Jmaps are created by using a spherical projection method. The advantage over SATPLOT is to be able to manipulate the images, and to synchronize the measured data points with movies.
Developed by N.R. Sheeley (NRL)



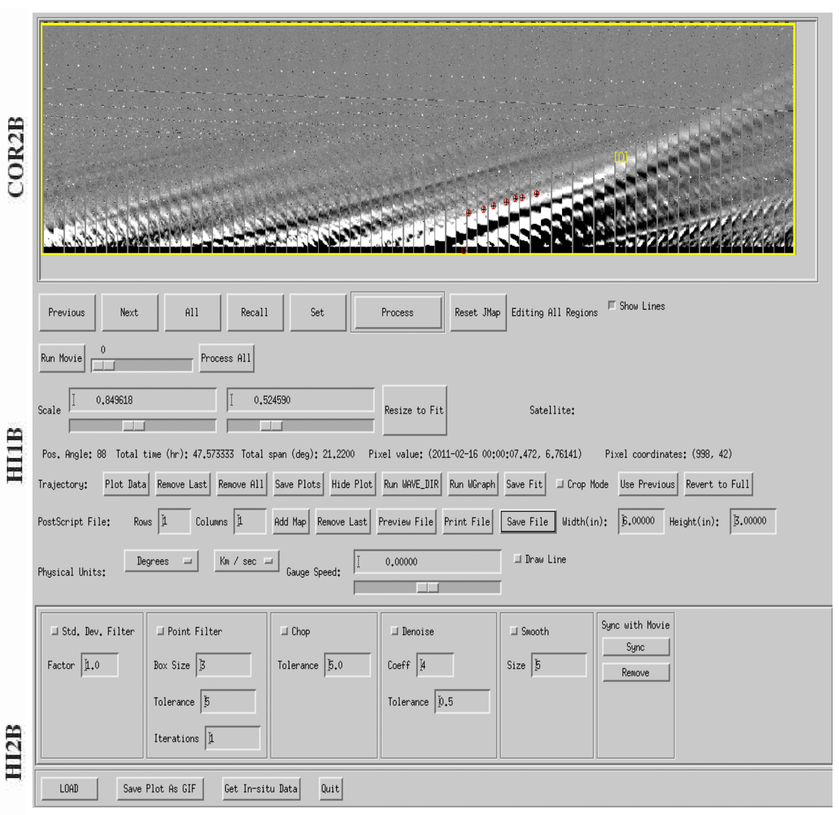


Figure 3: Userinterface of NRL-Tool with loaded jmap. The CME is marked with red crosses. Yellow marking denotes point, that can be checked (with the ‚Sync'-button) in the corresponding movie.

Figure 2: Difference images, produced while preparing the raw data. The off-pointed and wide-field HI1 and HI2 images are converted to a Sun-centered polar coordinate system with elongation angle along the radial direction and position angle around the azimut.

First results and Conclusion

Shown are the results for the June 2, 2008 CME event. The CME front could be tracked very well in both tools over all instruments (COR2-HI1-HI2) as can be seen in Figure 4. The maximum differences in elongation are of the order of 5°. Shifts are observed due to measurements coming from different instruments, more distinctly seen for NRL-tool measurements than for SATPLOT. We applied fitting routines to derive the speed (assumed to be constant) and the direction of motion of the CME. Differences in the results are of the order of 6 to 20° in direction and 8 to 46 km/s in speed. Compared to Temmer et al., 2011 (direction: E 30-50, speed:~350 km/s) the SSE - fitting derived the most reliable results for direction and speed.To get more conclusive results we will in the same way systematically test a set of 12 well-observed CME events.

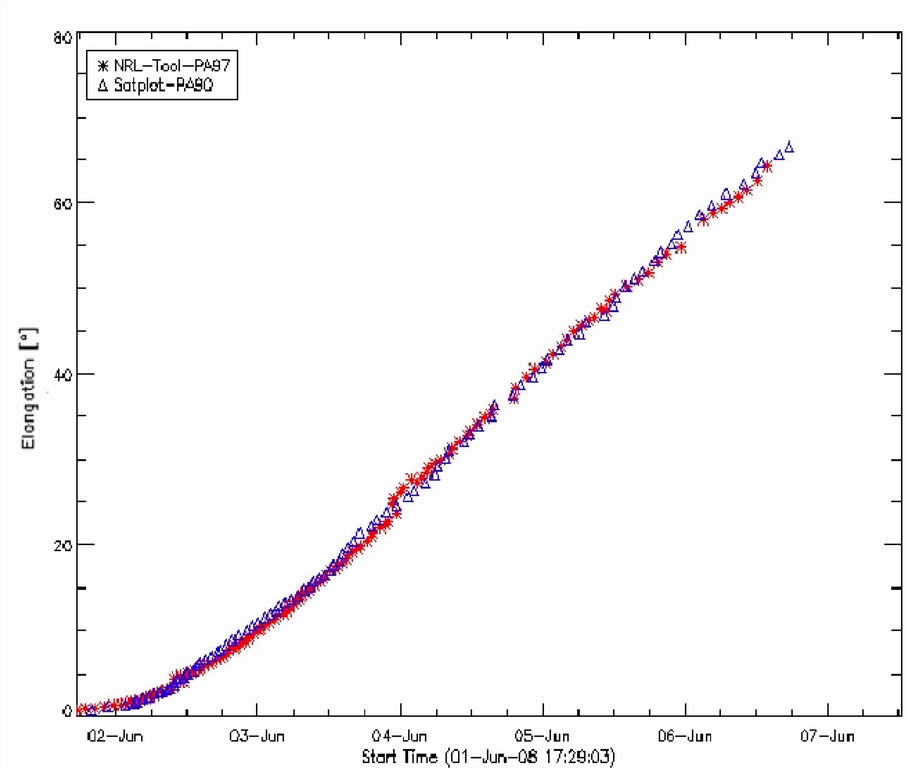
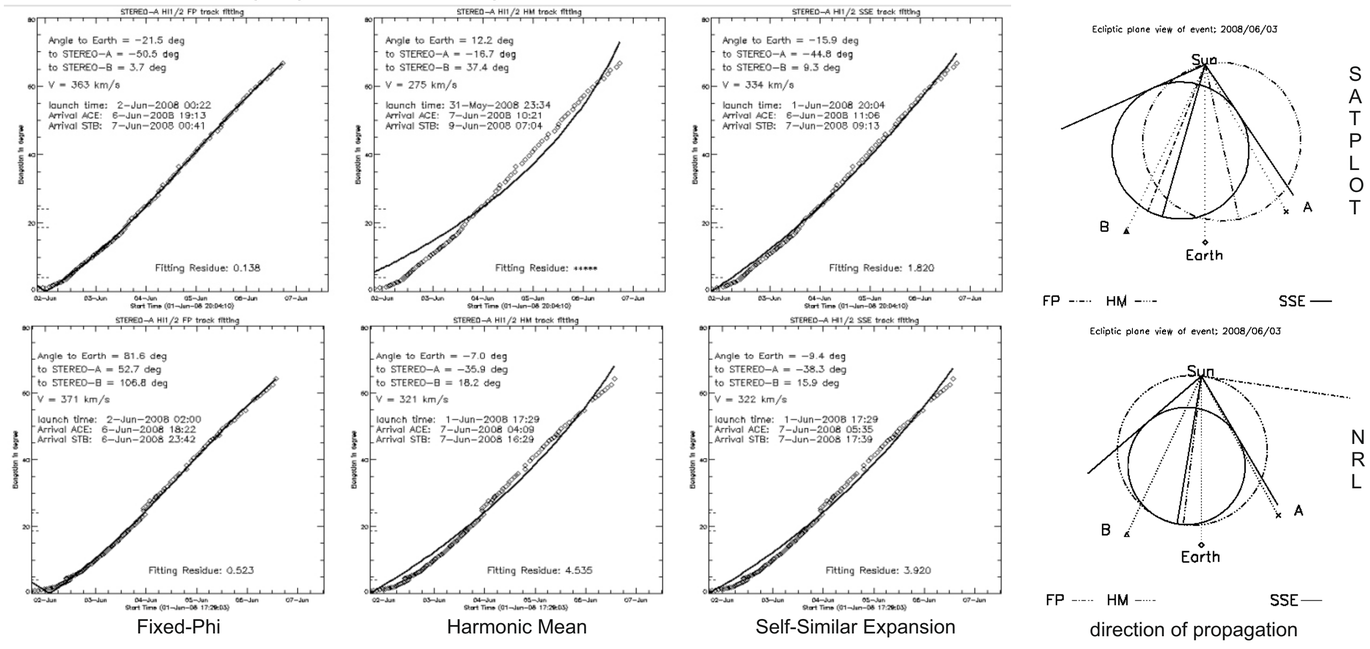


Figure 4: Elongation-time curves derived from SATPLOT Tool (blue triangles) and NRL Tool (red asterisks).



	FP (Speed)	HM (Speed)	SSE (Speed)	FP (Direction)	HM (Direction)	SSE (Direction)
SATPLOT	363 km/s	275 km/s	334 km/s	-21.5°	12.2°	-15.9°
NRL	(371 km/s)	321 km/s	322 km/s	(81.6°)	-7.0°	-9.4°
Diffrence	8 km/s	46 km/s	12 km/s	(103.1°)	19.2°	6.5°

Figure 5: Fitting results for the SATPLOT data in the upper panel and for the NRL data in the lower panel. We derive the CME speed, the direction (both assumed to be constant) and the arrival time. In the table the results for speed and direction and the diffrences are listed. In the last column the calculated directions of propagation for Fixed-Phi (FP), Harmonic Mean (HM) and Self-Similar Expension (SSE) are displayed (Möstl et al., 2014, in preparation).

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References: SATPLOT-User-Guide: http://hesperia.gsfc.nasa.gov/ssw/stereo/secchi/idl/jpl/satplot/SATPLOT_User_Guide.pdf
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Sheeley et al., 1999, JGR, Volume 104, Issue A11, p. 24739-24768
Lugaz et al., 2009, AnGeo, Volume 27, Issue 9, pp.3479-3488
Davies et al.,2012 ApJ, Volume 750, Issue 1, 12 pp.
Temmer et al., 2011 ApJ, Volume 743, Issue 2, 12 pp.