SMEI Observations of the Heliosphere During WHI

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Abstract: Solar Mass Ejection Imager (SMEI) observations of the inner heliosphere have been carried out on a routine basis since early 2003. By employing a kinematic model of the solar wind, we reconstruct three-dimensional (3D) solar wind structures from multiple observing lines of sight through the outward-flowing solar wind. These models allow us to extract solar wind density and to compare these to "ground truth" measurements from multi-point in-situ solar wind measurements from the STEREO, SOHO, ACE, and the Wind spacecraft. This aids in improving the 3D reconstruction technique by comparing these reconstructions at multiple points in the inner heliosphere. Because our observations reveal the global nature of heliospheric structures, this also leads to a better understanding of the structure and dynamics of the interplanetary environment around each spacecraft, and how these structures are connected back to the Sun. During the Whole Heliosphere Interval (WHI) SMEI will provide views and 3D reconstructions of the global heliosphere that can be compared with ground-based and spacecraft observa-tions. See: **http://smei.ucsd.edu**

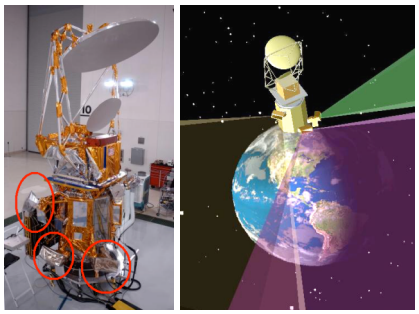
Introduction:

Following the successful launch of the Solar Mass Ejection Imager (SMEI) on 6 January 2003 (Eyles *et al.*, 2003; Jackson *et al.*, 2004), we have been developing an image analysis technique that, as much as possible, retains the long-term brightness variation and data frame resolution of the instrument. We provide this data base partially to provide a tomographic analysis of heliospheric structures that include both CMEs and longer-term heliospheric density structures such as the extensions of coronal streamers. SMEI observations since launch have been available on the NSO website **http://smei.nso.edu/** in near real time as quick-look data.

SMEI (Figure 1) records nearly the whole sky data on each 102-minute orbit from 840 km. On board the Coriolis spacecraft, SMEI rotates once per orbit and views three strips of sky away from Earth using CCD camera technology.

The three cameras on SMEI have been used to provide sky maps that include orbit differences that have provided images from which a long-term base has been removed. These have been turned into time series (Figure 2) at given sidereal locations in order to provide brightness over time that can be used in the 3D reconstruction program analysis at UCSD (Figure 3). For selected time intervals these provide comparisons with in situ data at Earth (Figure 4).

The 27-28 May 2003 coronal mass ejection (CME) event sequence has been studied in this manner (Jackson *et al.*, 2008). The ejected material is associated with a sequence of halo CMEs and X-ray flares from NOAA active region 10365 located at ~S07 W14 [*Solar Geophysical Data*, Part II]. Each halo CME that follows in the sequence has a larger sky plane speed measured in the LASCO coronagraph such that the last event in the sequence catches the first to provide the bulk of the mass measured near 1 AU on 30 May 2003 and imaged as a remote observer would view this mass as shown in Figure 3.



(a) (b)

Figure 1. **(a)** The Coriolis spacecraft with the Solar Mass Ejection Imager (SMEI) instrument and the *Windsat* antenna prior to launch from Vandenberg AFB. The three camera baffles (circled) are seen on the lower portion of the spacecraft. **(b)** SMEI in its terminator polar orbit at 840 km with an orbital inclination of 98°. SMEI looks away from the Earth at 30° above the local horizontal to avoid sunlight reflected from the Earth and from the *Windsat* antenna. The fields of view of the three cameras (each shown as shaded extensions from the satellite) together cover nearly 180° of sky, and as the instrument orbits Earth, map out nearly the whole sky around it.

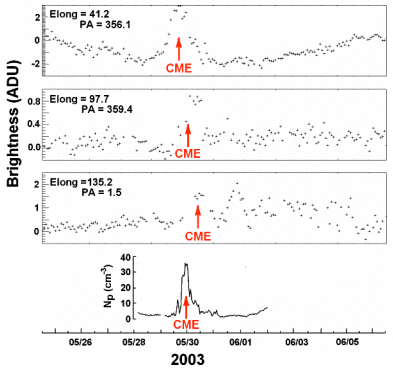


Figure 2. Measurements obtained during the 27-28 May 2003 halo CME sequence. The three upper panels show examples of SMEI brightness time series in ADU (at 102-minute intervals) from individual square degrees of sky at different angular distances from the Sun, after removing a long-term base. The lower panel shows hourly-averaged level-0 proton density from the Advanced Composition Explorer Solar Wind Electron Proton Alpha Monitor (ACE/SWEPAM) instrument.

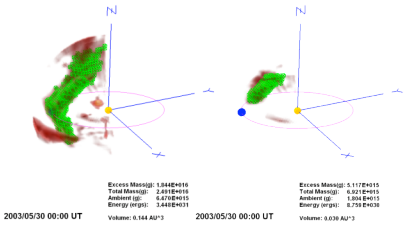


Figure 3. 3D mass determination for the 27-28 May 2003 halo CME sequence as the CMEs reach Earth at 00 UT on 30 May 2003. Electron density is contoured upward from 15 cm^{-3}. **(left)** The total event is highlighted and filled with cubes, has a volume of 0.144 AU^3 above this contour interval, and a total mass of 2.49 × 10^{16}g. **(right)** A small portion of the event that has been followed outward associated with a LASCO C3 coronagraph observed CME to the solar northeast first observed at 03:26:06 UT on 27 May 2003. It has a volume of 0.030 AU^3 and an excess mass of 5.1 × 10^{15}g and a total mass of 6.9 × 10^{15}g. These values are in excellent agreement with those from the LASCO coronagraph. The excess mass observed for this event in LASCO C3 is listed as 2.3 × 10^{15}g, and approximately doubles if the event is 60° from the sky plane as is indicated by the 3D reconstructions from SMEI observations.

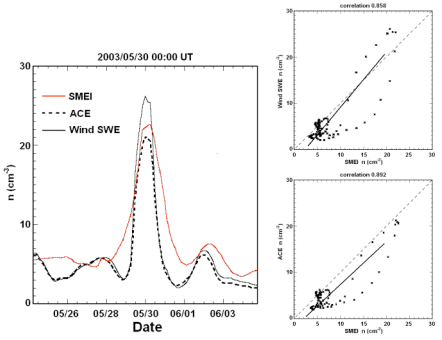


Figure 4. (left) SMEI 3D reconstructed proton density compared with ACE/SWEPAM level-2 and Wind Solar Wind Experiment (SWE) *in situ* data over the interval indicated from the event sequences shown in Figures 2 and 3. Because SMEI observes electrons, a 10% helium abundance is assumed to provide the correct proton numbers for comparison *in situ*. **(right)** Correlation over the time interval shown between the 3D reconstruction and ACE and Wind measurements. The ACE and Wind data have been "boxcar" averaged over one-day to better fit the low resolution available from the 3D reconstruction.

UCSD SMEI Database during the WHI period:

UCSD has maintained a SMEI data archive, and website at **http://smei.ucsd.edu/** that provides access to the individual SMEI data frames and processed sky maps. These include higher-level data products for some selected intervals including those during the 2008 WHI period from 20 March to 16 April 2008 (CR 2068). From this data base we are studying UCSD 3D heliospheric reconstructions during the interval, a sample of which are shown in Figure 5.

We have several 3D reconstruction parameters that it is possible to adjust, and different ways to interpret our analyses now that the STEREO *in situ* measurements are available; and these WHI analyses are subject to revision as we study our results more thoroughly. In the Figure 5 analyses we have eliminated some of SMEI camera 3 data (noisy in the current UCSD 2008 data set) by using lines of sight >70° elongation in the 3D reconstructions.

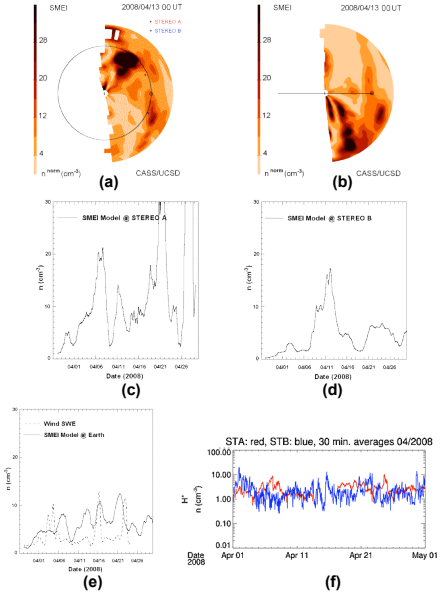


Figure 5. SMEI **a)** ecliptic and **b)** meridional 3D reconstruction cuts at Earth at 00 UT on 13 April 2008. Model and *in situ* location proton densities at **c)** STEREO A, **d)** STEREO B, **e)** Earth compared with Wind, **f)** STEREO A and STEREO B.

REFERENCES:

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