3D CME Parametrization - Comparison of GCS and CAT techniques and ENLIL applications

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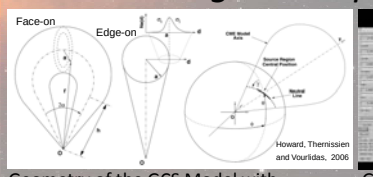
Introduction

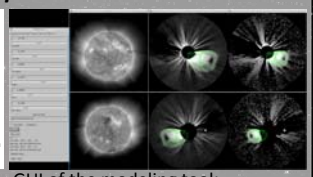
Since launch of the STEREO twin spacecraft in October 2006, 1071 large-scale flux-rope like CMEs were identified in STEREO/SECCHI/COR2 observations between January 2007 and December 2011 covering the full range of spacecraft separation angles between 0° and 180°. Based on their bright and clear white-light appearance in the COR2 field of view 241 CMEs were selected and analyzed with the Graduated Cylindrical Shell (GCS) modeling technique [1]. For a set of selected CMEs their 3D topology, direction of propagation and speed was analyzed based on multipoint observations (STEREO and SOHO Beacon data) with the CME Analysis Tool (CAT) [2]. The results originated from this CME analysis are used as input for the forecast of space storms at Earth's orbit by ENLIL and other models.

GCS Modeling Technique

CME observed on 12.03.2011

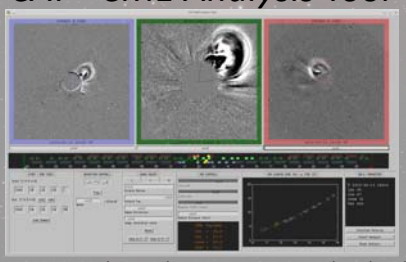


Geometry of the GCS Model with Electron density distribution.
6 parameters describing the geometry



GUI of the modeling tool: Control Panel, EUVI, COR2 science and COR2 beacon data

CAT - CME Analysis Tool



CME #389 observed on 13.04.2010; analyzed with STEREO/COR2 and SOHO/C2 C3 beacon data

Lon: 47.0°
Lat: 35.0°
Half Angle: 31.5°
Speed: 464 km/s
at 21.5 r_{sun}:
Date 13.04.2010
Time 18:20 UT

ENLIL

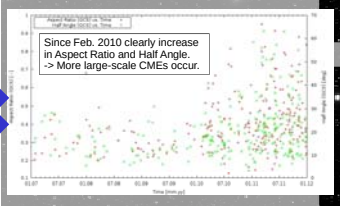
Comparison of both techniques

Graduated Cylindrical Shell (GCS)	CME Analysis Tool (CAT)
Flux tube model, „croissant" like shape with electron density distribution, ray-tracing code	Ice cream cone model
Usage with science data (and beacon data): STEREO/COR2, SOHO/C2 C3, STEREO/EUVI	Usage with beacon data: STEREO/COR2, SOHO/C2 C3
Carrington Lon., Heliospheric Lat. [deg]	Heliospheric Lon., Heliospheric Lat. [deg]
Half Angle (between legs) [deg], Height [r_{sun}]	Half Angle (cone) [deg], Distance [r_{sun}]
Tilt Angle [deg], Aspect Ratio [--]	Linear Velocity determination
Single Fit Tool for science purpose	Multi Fit Tool for forecast purpose (-> ENLIL)

Results: GCS and CAT

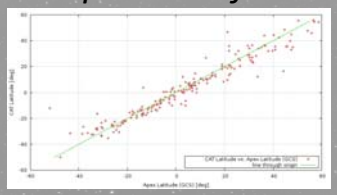
Total CME List (2007 - 2011): 1071 CMEs detected with STEREO/SECCHI/COR2.
„Best-of" CME List: 241 CMEs analyzed with GCS and CAT modeling technique.

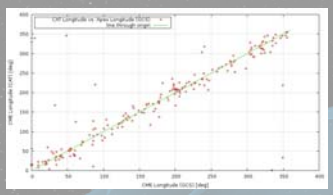
Parameter		Range	For x % of all fits
Latitude [deg]	GCS	-40 .. +40	90%
Tilt Angle [deg]		-40 .. +40	80 %
Aspect Ratio [--]		0.2 .. 0.6	85 %
Half Angle [deg]		10 .. 30	71 %
Height [r_{sun}]		10 .. 15	71 %
Latitude [deg]	CAT	-40 .. +40	93%
Half Angle, Cone [deg]		16 .. 40	79%
Speed [km/s]		200 .. 1000	90%



Comparison of results

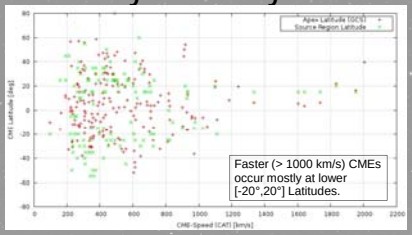
Longitude and Latitude of Apex of CME leadingedge projected on solar surface.



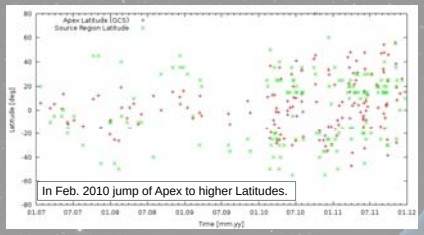


For 80 % of all events (196) deviations exhibit max. ± 20° in Carrington Longitude.
For 90 % of all events (196) deviations exhibit max. ± 10° in Heliospheric Latitude.

Results for CME forecast

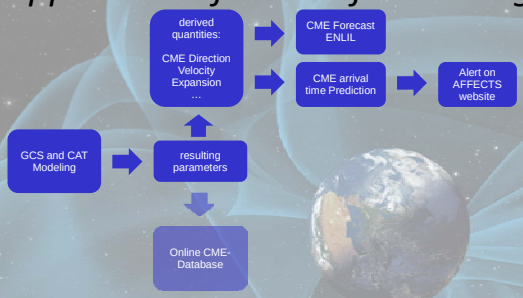


Source Regions (SR) of CMEs were identified in STEREO/SECCHI/EUVI data.
73% of all events show a discrepancy in Latitude of 0°-20° between SR position and modeled CME.



Deflection of CMEs to lower Latitudes observable from Feb. 2010 on.

Applications for CME forecasting



References:

[1] Thernisien,Vourlidas,Howard: Forward Modeling of CMEs using STEREO/SECCHI Data, *Solar Phys. (2009), 256: 111-130.*

[2] Millward, Biesecker, Pizzo, de Koning: An operational software tool for the analysis of coronagraph images: Determining CME parameters for input into the WSA-Enlil heliospheric model, Space Weather (2013), VOL. 11, 57-68.

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