Propagation and space-weather Tools

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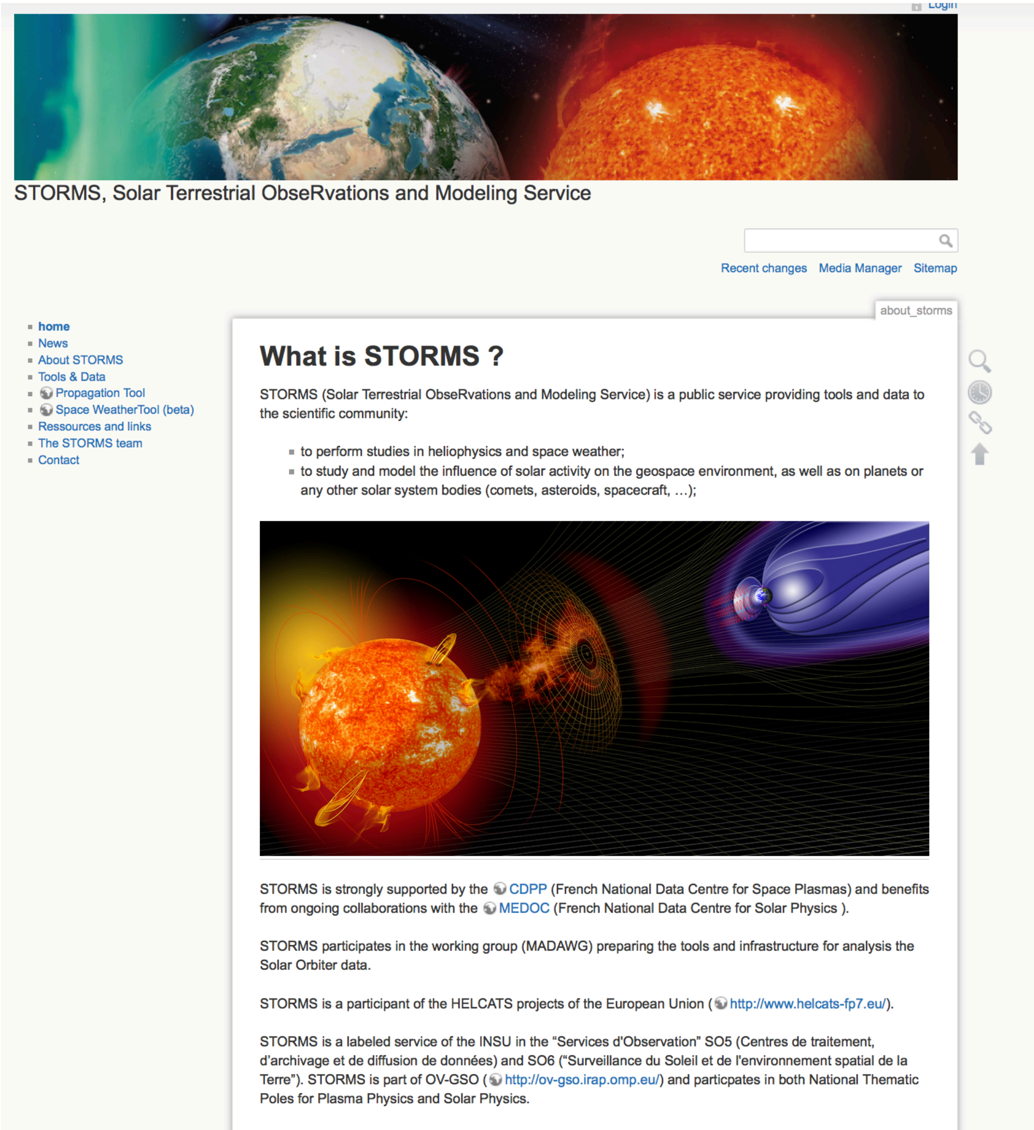
(1) IRAP-CNRS / UPS, (2) George Mason University, (3) NOAA

PROPAGATION TOOL: propagationtool.cdpp.eu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STORMS, Solar Terrestrial ObseRvations and Modeling Service

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about_storms

What is STORMS ?

STORMS (Solar Terrestrial ObseRvations and Modeling Service) is a public service providing tools and data to the scientific community:

- to perform studies in heliophysics and space weather;
- to study and model the influence of solar activity on the geospace environment, as well as on planets or any other solar system bodies (comets, asteroids, spacecraft, …);

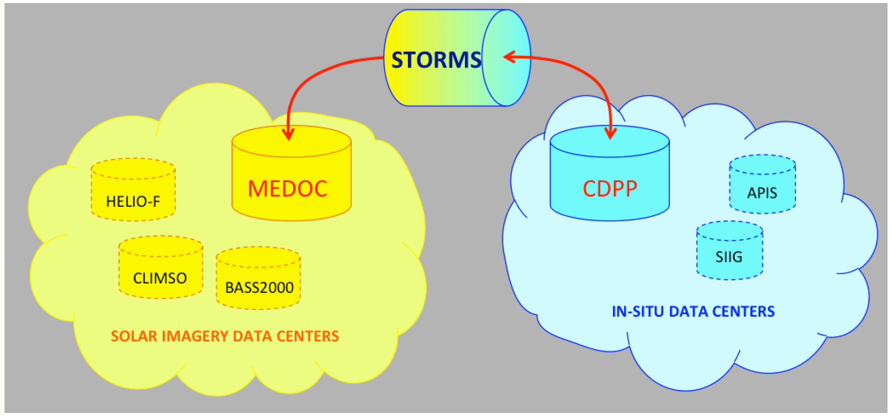
STORMS is strongly supported by the CDPP (French National Data Centre for Space Plasmas) and benefits from ongoing collaborations with the MEDOC (French National Data Centre for Solar Physics).

STORMS participates in the working group (MADAWG) preparing the tools and infrastructure for analysis the Solar Orbiter data.

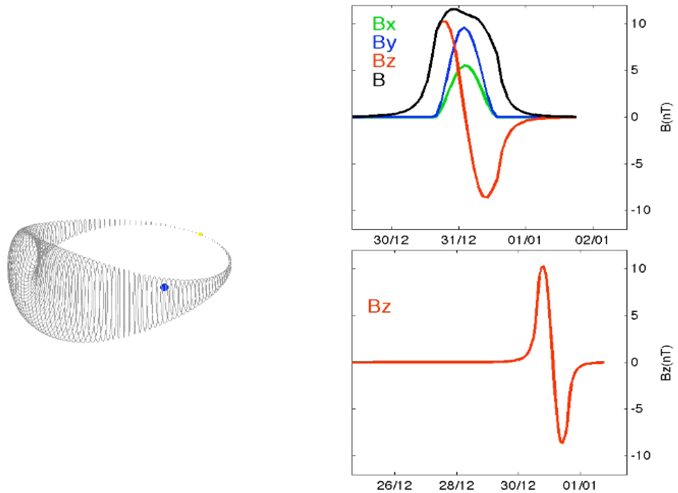
STORMS is a participant of the HELCATS projects of the European Union (http://www.helcats-fp7.eu/).

STORMS is a labeled service of the INSU in the "Services d'Observation" SO5 (Centres de traitement, d'archivage et de diffusion de données) and SO6 ("Surveillance du Soleil et de l'environnement spatial de la Terre"). STORMS is part of OV-GSO (http://ov-gso.irap.omp.eu/) and particpates in both National Thematic Poles for Plasma Physics and Solar Physics.

Connecting datasets:



Developing space-weather apps:



-> A tool to help scientists (working on the Sun, the interplanetary medium and planets).

The tool was created to:

- Provide a summary view of the position of spacecraft, planets, the orientation of cameras, simple localisation of CMEs, flares, CIRs) and in-situ data.
- Provide a summary view of all HELCATS catalogues (CIRs, CMEs),
- Provide access to the simplest fitting techniques (Fixed points, SSE),
- Provide easy access to data centers including their respective tools (JHelioviewer, AMDA)
- Run on all OSs (Mac, Windows, Linux),
- Retain long-term funding (support of the French space agency (CNES) and CNRS).

Welcome to CDPP/Propagation Tool

Tutorials : video (mov files)

- Introduction to the CDPP Propagation Tool (13M)
- Description of the propagation tool main interface (8M)
- Case 1: Using the tool in the Jmap Carrington/In situ mode (radial) (37M)
- Case 2: Using the tool in the Jmap tool click mode (radial) (39M)

Tutorials : video (mpeg files)

- Introduction to the CDPP Propagation Tool (46M)
- Description of the propagation tool main interface (47M)
- Case 1: Using the tool in the Jmap Carrington/In situ mode (radial) (176M)
- Case 2: Using the tool in the Jmap tool click mode (radial) (184M)

Table of available data

- Flare Data, Carrington Maps, J-Maps, Solar Wind Speed

Supported set up

- Check browser/OS support
- Java requirements
- Get java 7.45
- Linux troubleshoot

What's new ?

- New J-maps will be available in February 2014

Launch the Propagation Tool

A new interactive tool accessible to the solar, heliospheric and planetary science communities to track solar storms, streams and energetic particles in the heliosphere

The propagation tool allows users:

- to propagate solar eruptions (CMEs) radially sunward or anti-sunward (**Radial Propagation**),
- to propagate corotating structures (CIRs) in the heliosphere (**Corotation**),
- to propagate solar energetic particles along magnetic fields lines sunward or anti-sunward (**SEP Propagation**),

The START and END points (defined by a right click on the ecliptic plane) can be the Sun, planets or probes situated in the interplanetary medium. The times of propagation between the START and END points are based on simple analytic calculations.

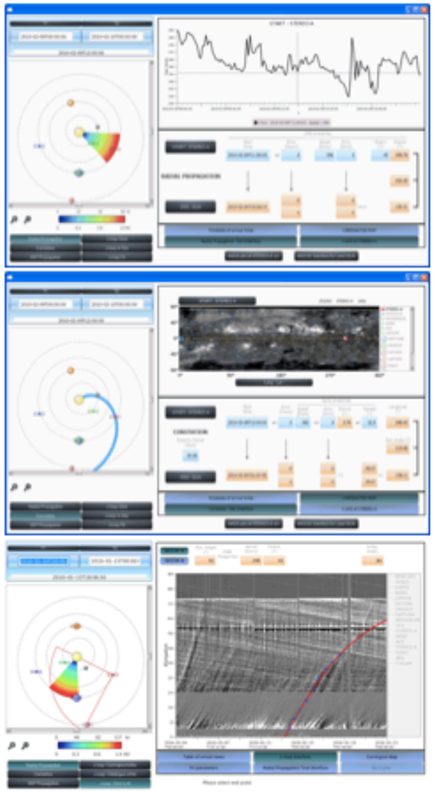
The added values of the tool are an easy access to unique datasets and a fast interoperability :

- it integrates the **orbital elements** (using SPICE) of probes and planets. This allows you to determine via simple clicks the position/orientations of imagers that you would like to consider,
- it offers **web-service** access to summary plots of in-situ data stored at the CDPP as well as movies of solar images stored at MEDOC,
- it provides access to a wide range of **Carrington maps** of the solar surface to visualize the location of active regions, coronal holes and solar flares on the Sun

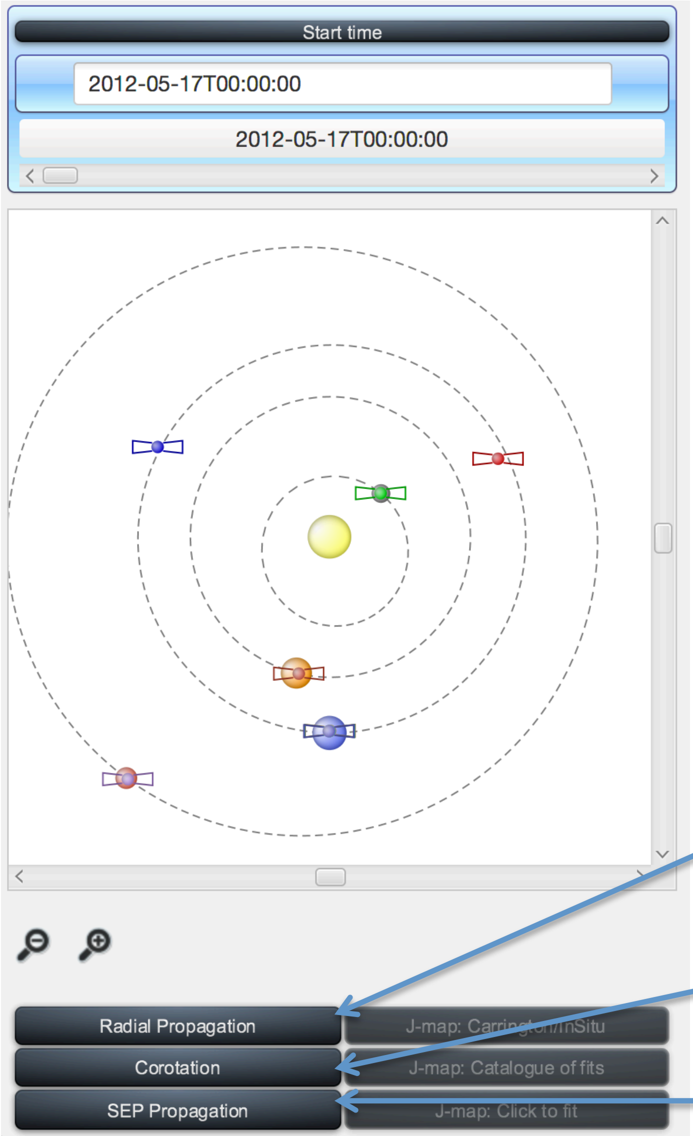
The great novelty of the tool is the immediate visualisation and basic manipulation of maps of solar wind mass flows tracked continuously from the Sun to 1AU. These maps are called J-maps and are generated by extracting bands of pixels in coronal and heliospheric images along the ecliptic planes and stacking them vertically (along the ordinate) with time (along the abscissae). The maps are produced from teraoctets of imagery data that are impossible to manipulate if you are not an expert in the field. The tool was designed to be user friendly and accessible to any scientist interested in locating CMEs/CIRs and particle fluxes in the ecliptic plane.

With the tool you can use these maps to:

- cross check your ballistic calculation of CME/CIR propagations,
- carry out your own calculations of CME/CIR trajectories in the ecliptic plane via a few clicks on the map (simple use),
- use pre-calculated CME trajectories to check if a transient emerged from the Sun and impacted a planet or probe



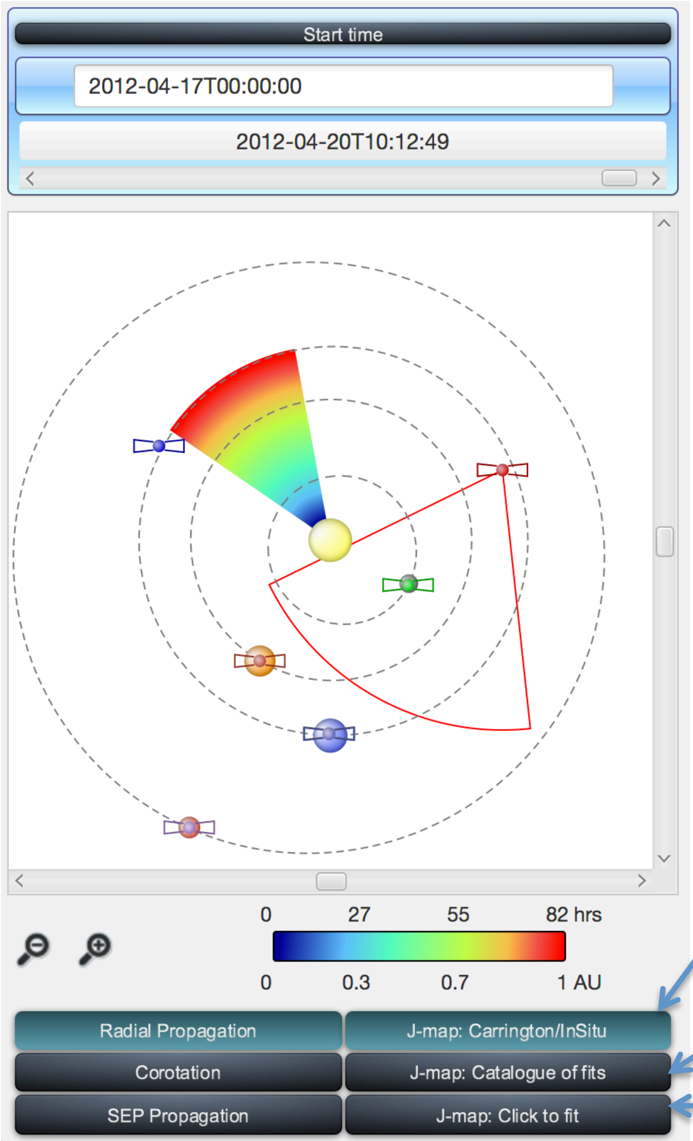
PROPAGATION TOOL: propagationtool.cdpp.eu



Radial propagation (CME like: ballistic, fixed point, self-similar techniques)

Corotation (CIR like: ballistic, fixed point)

SEP propagation (ballistic along simple Parker spiral)

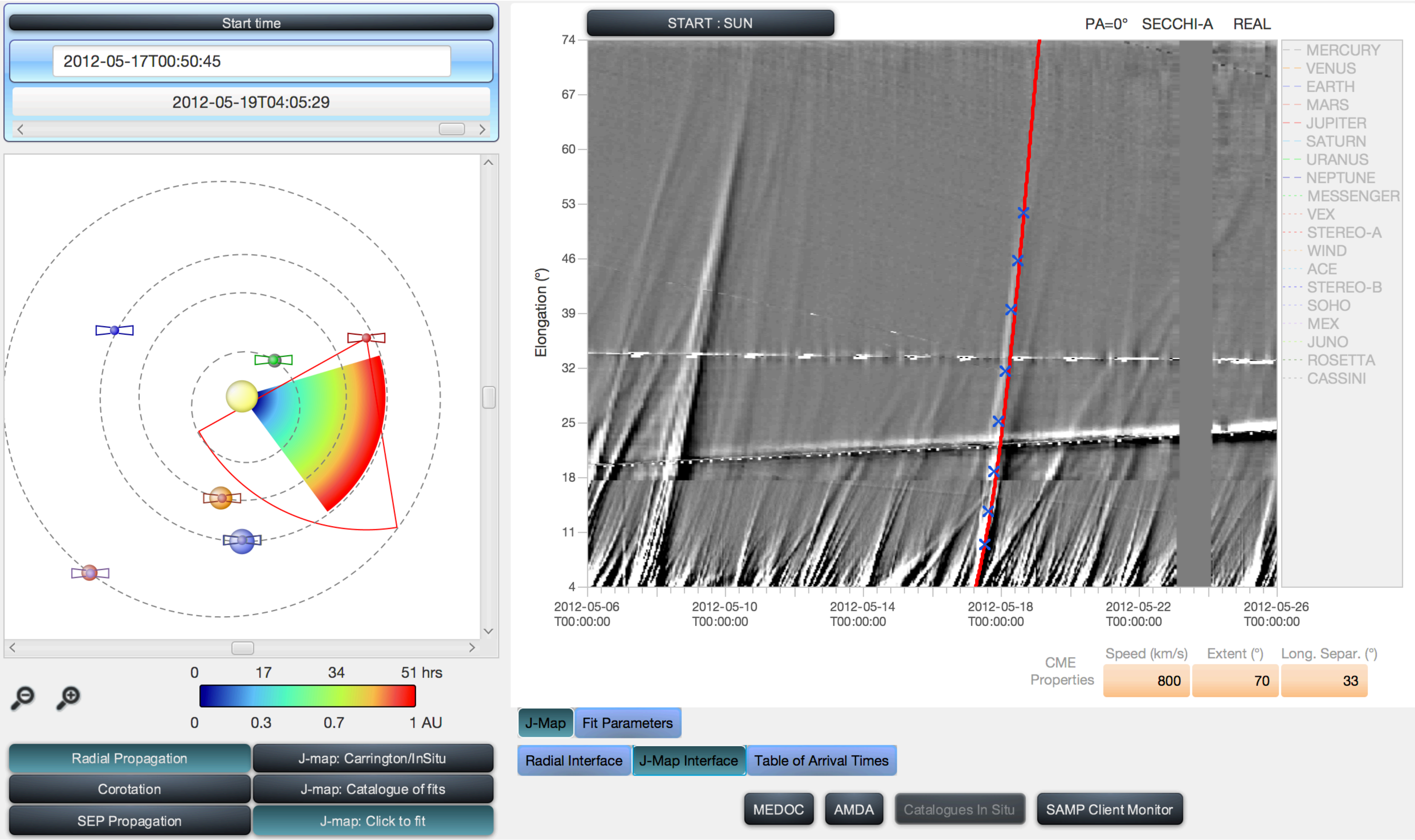


Tool to propagate a hypothetical CME (source region/ speed, access to Drag-Based Model)

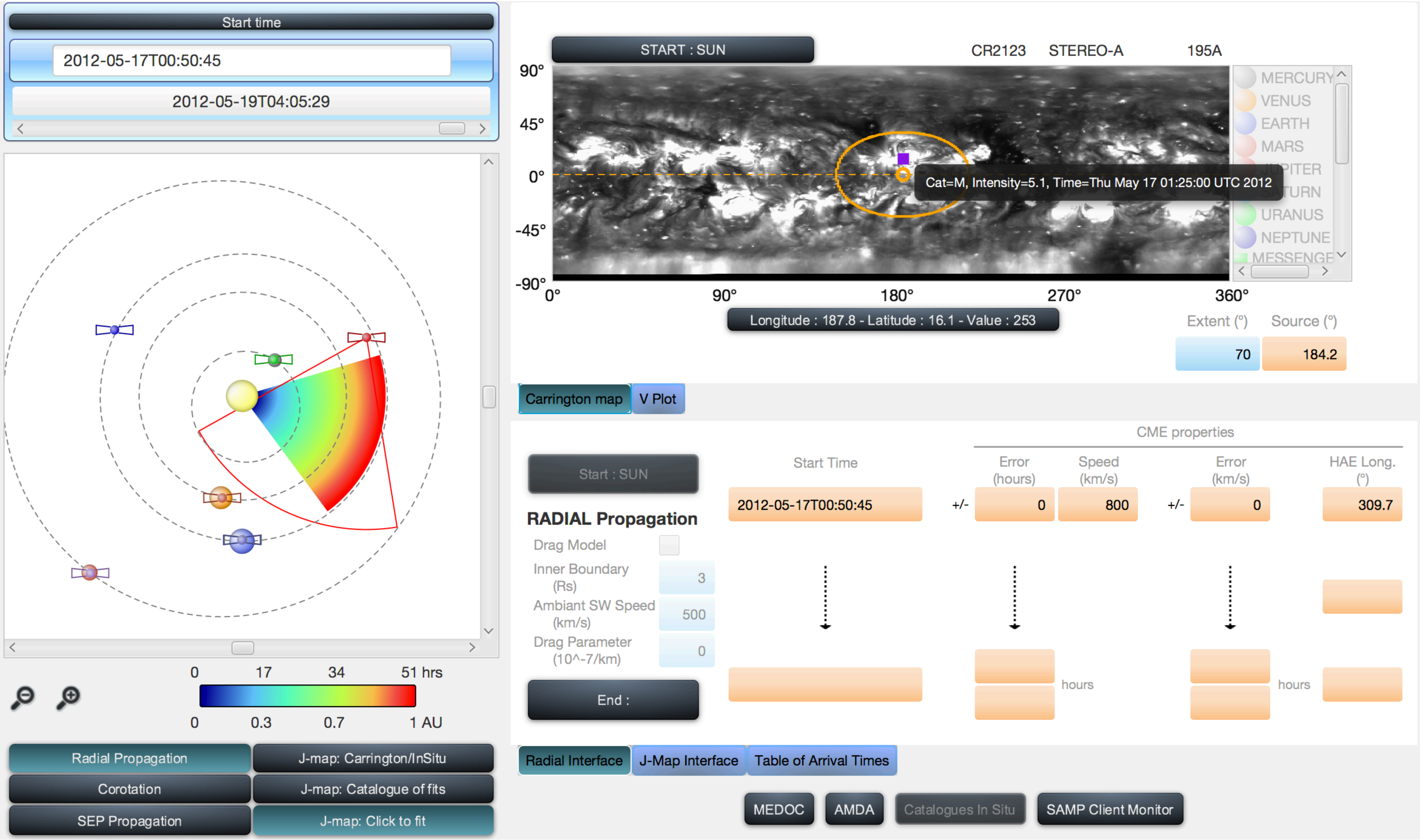
Tool to access HELCATS catalogues (CMEs and CIRs)

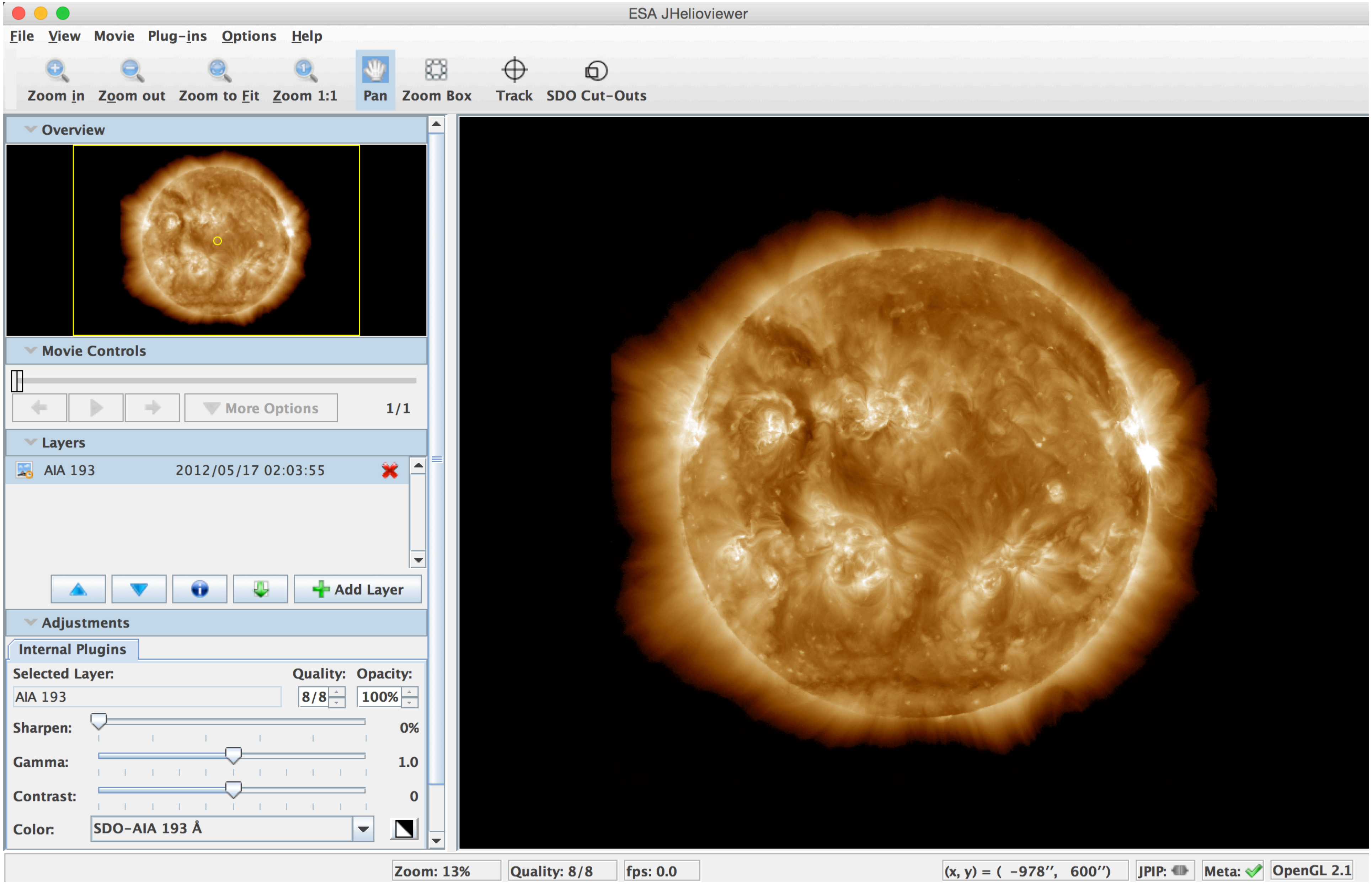
Tool to carry out your own fits (fixed point).

Inclusion of ENLIL J-maps

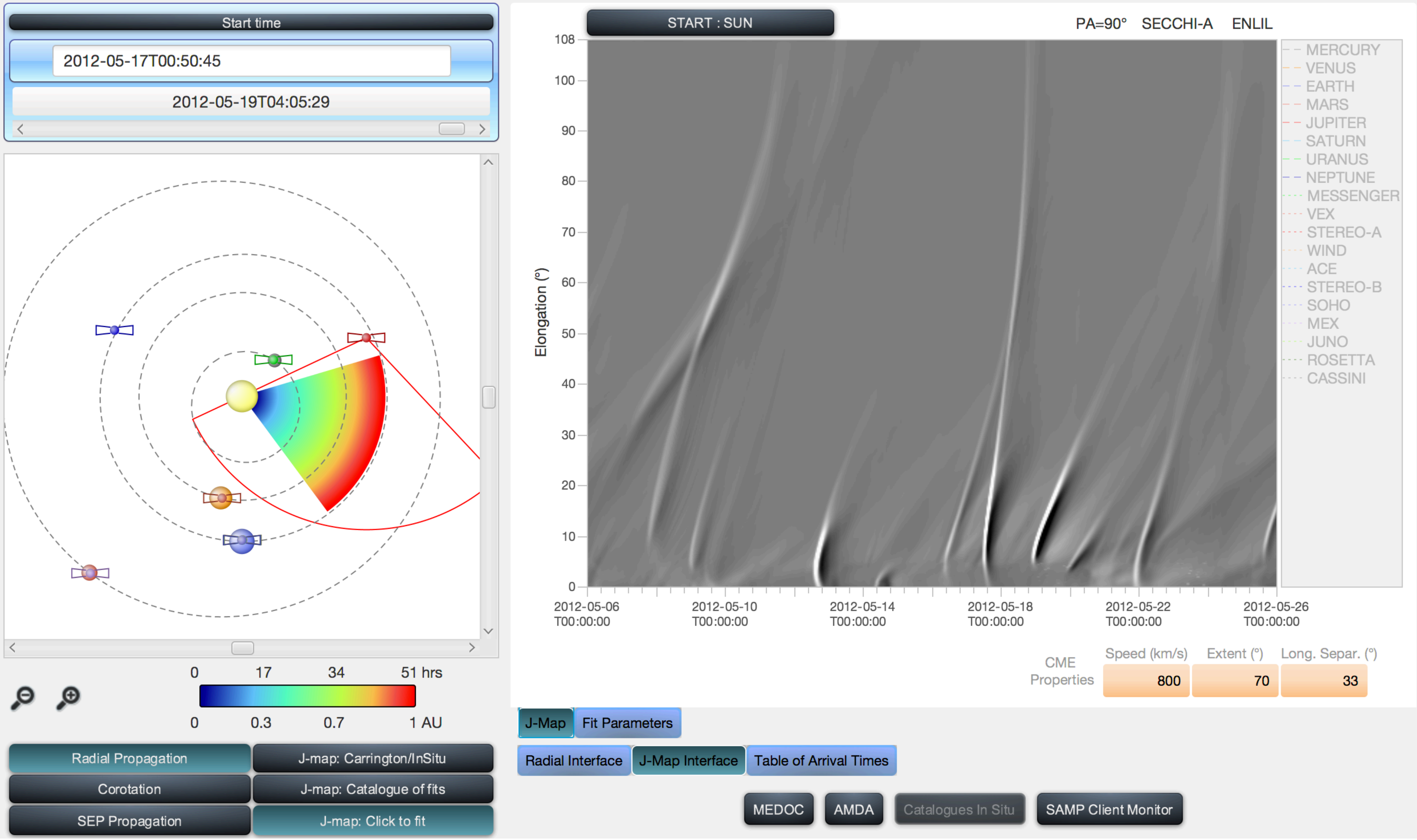


Inclusion of ENLIL J-maps:

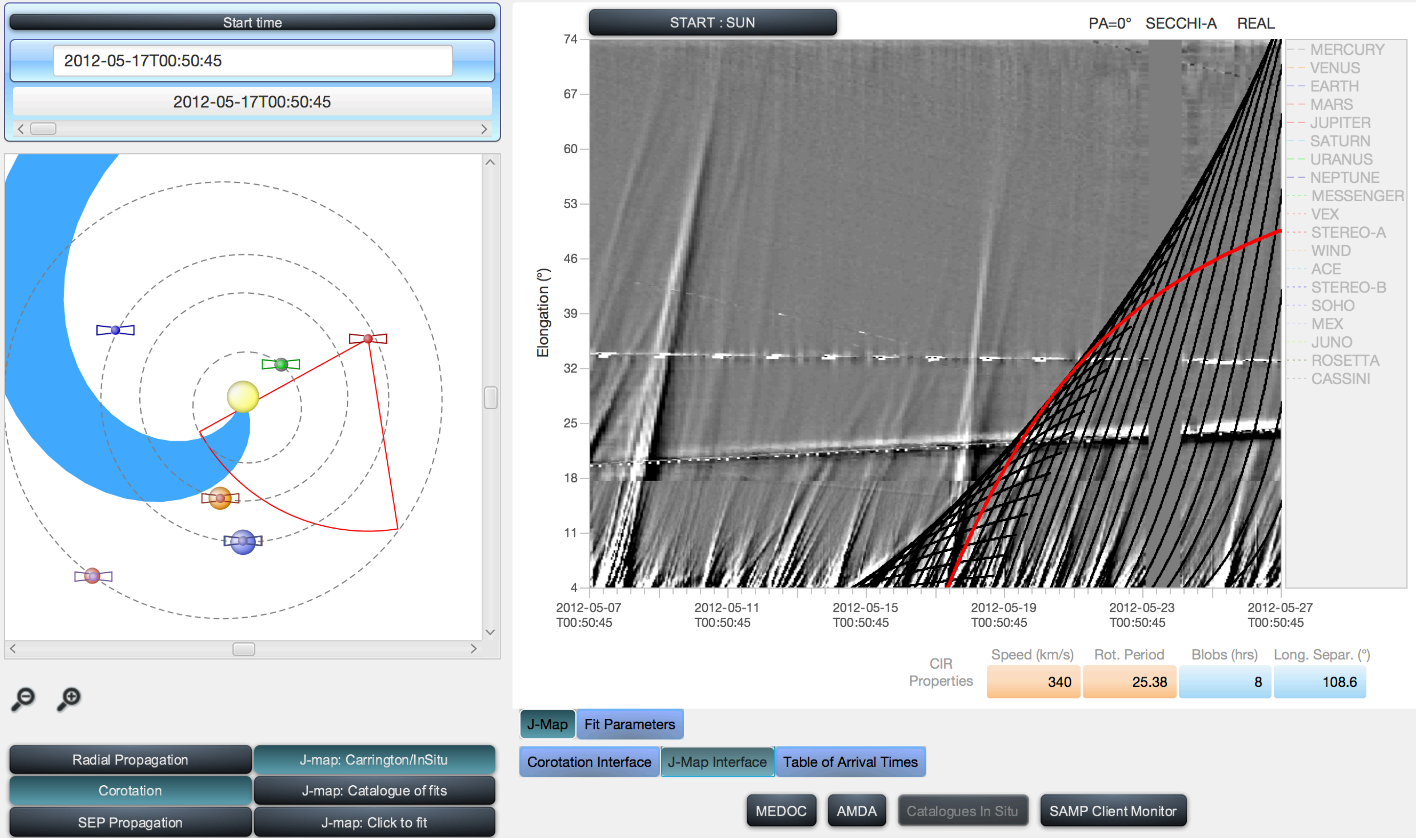



ESA JHelioviewer
File View Movie Plug-ins Options Help
Zoom in
Zoom out
Zoom to Fit
Zoom 1:1
Pan
Zoom Box
Track
SDO Cut-Outs
Overview
Movie Controls
More Options
1/1
Layers
AIA 193
2012/05/17 02:03:55
Add Layer
Adjustments
Internal Plugins
Selected Layer:
Quality:
Opacity:
AIA 193
8/8
100%
Sharpen:
0%
Gamma:
1.0
Contrast:
0
Color:
SDO-AIA 193 Å
Zoom: 13%
Quality: 8/8
fps: 0.0
(x, y) = (-978″, 600″)
JPIP:
Meta:
OpenGL 2.1

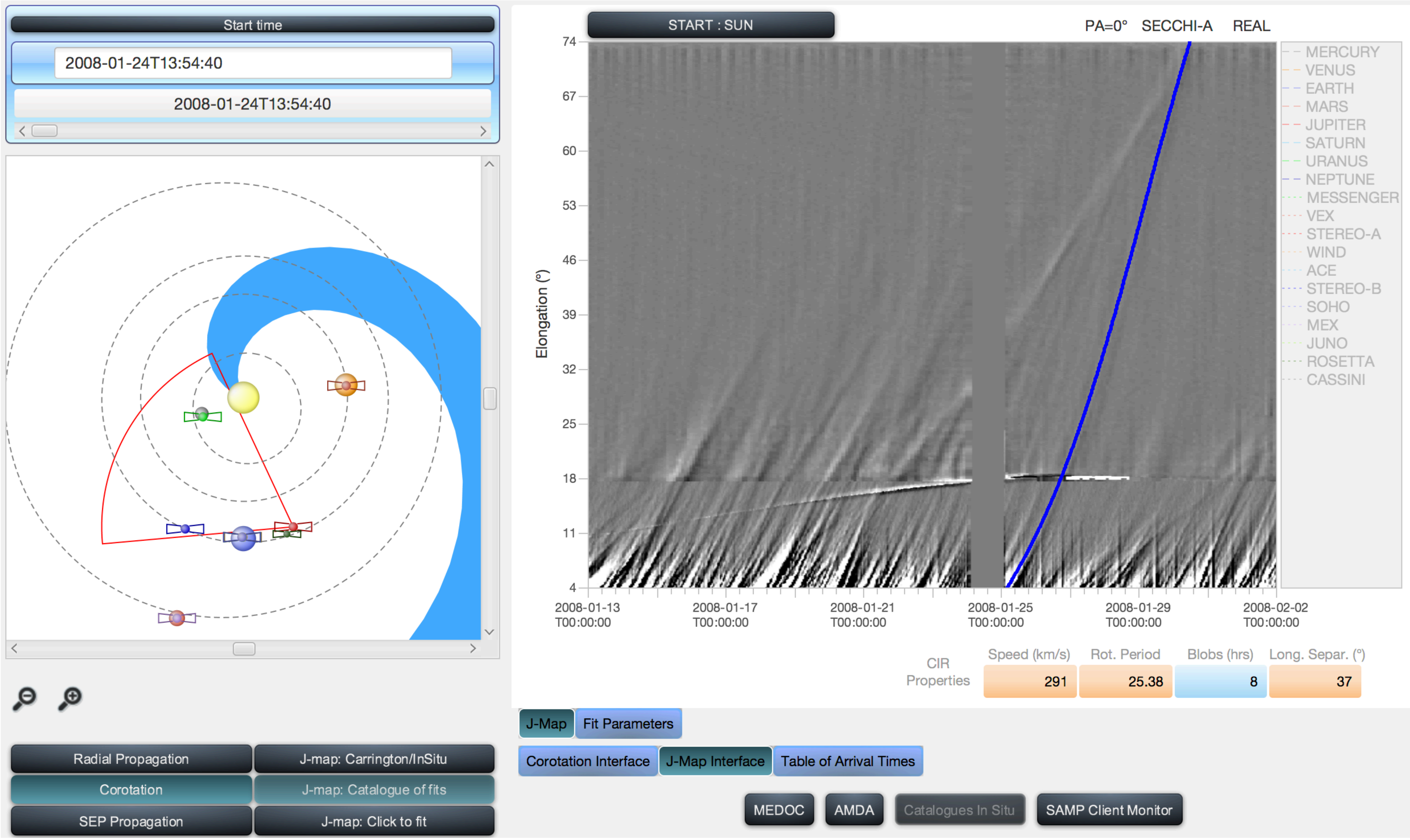
Inclusion of ENLIL J-maps



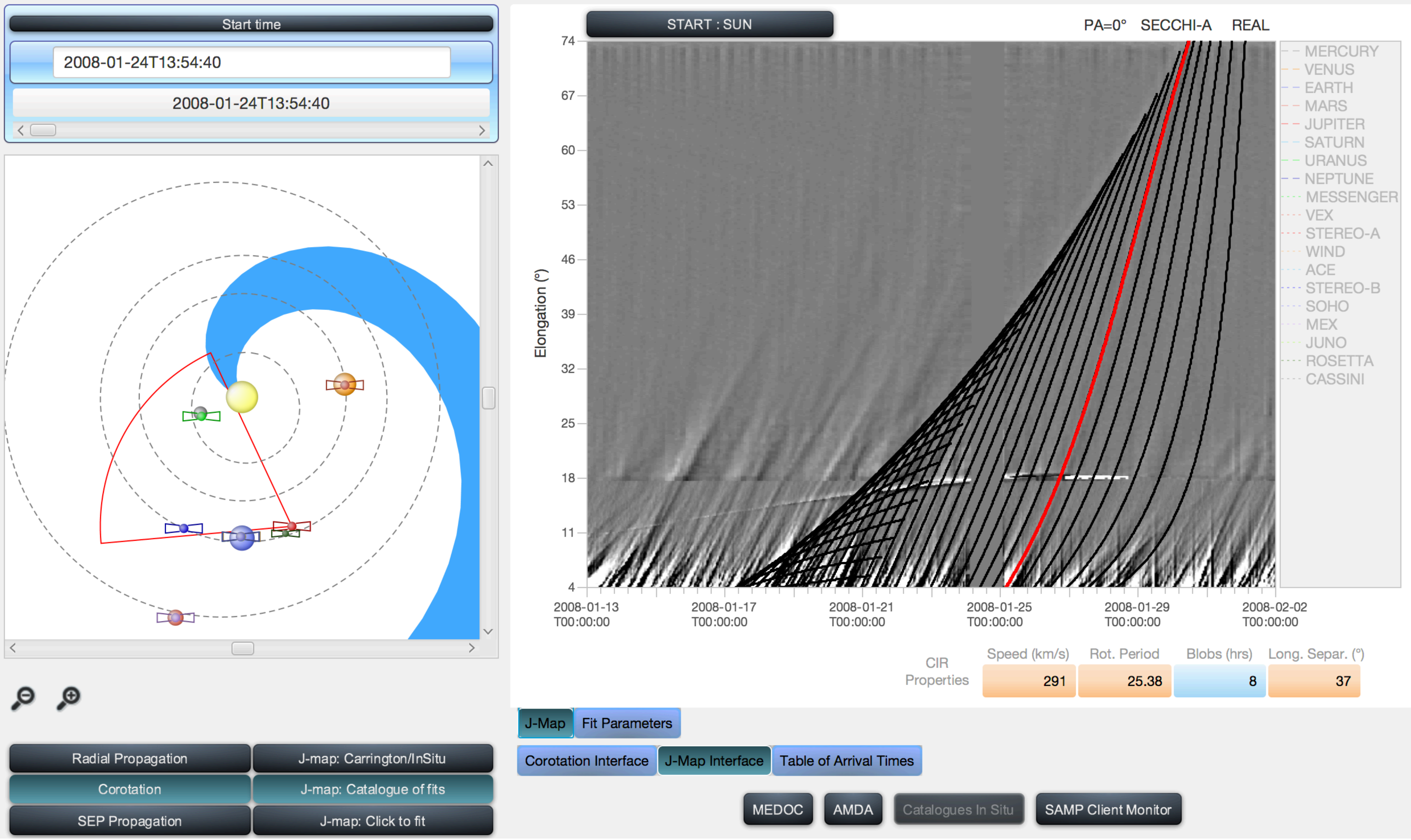
Inclusion of ENLIL J-maps



Inclusion of Illya's CIR catalogue



Inclusion of Illya's CIR catalogue

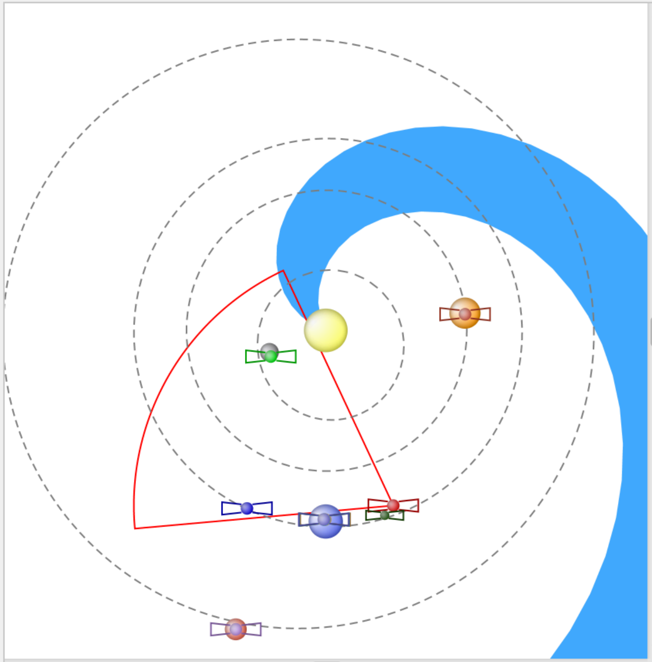


Inclusion of Illya’s CIR catalogue

Start time

2008-01-24T13:54:40

2008-01-24T13:54:40



Radial Propagation | J-map: Carrington/InSitu
Corotation | J-map: Catalogue of fits
SEP Propagation | J-map: Click to fit

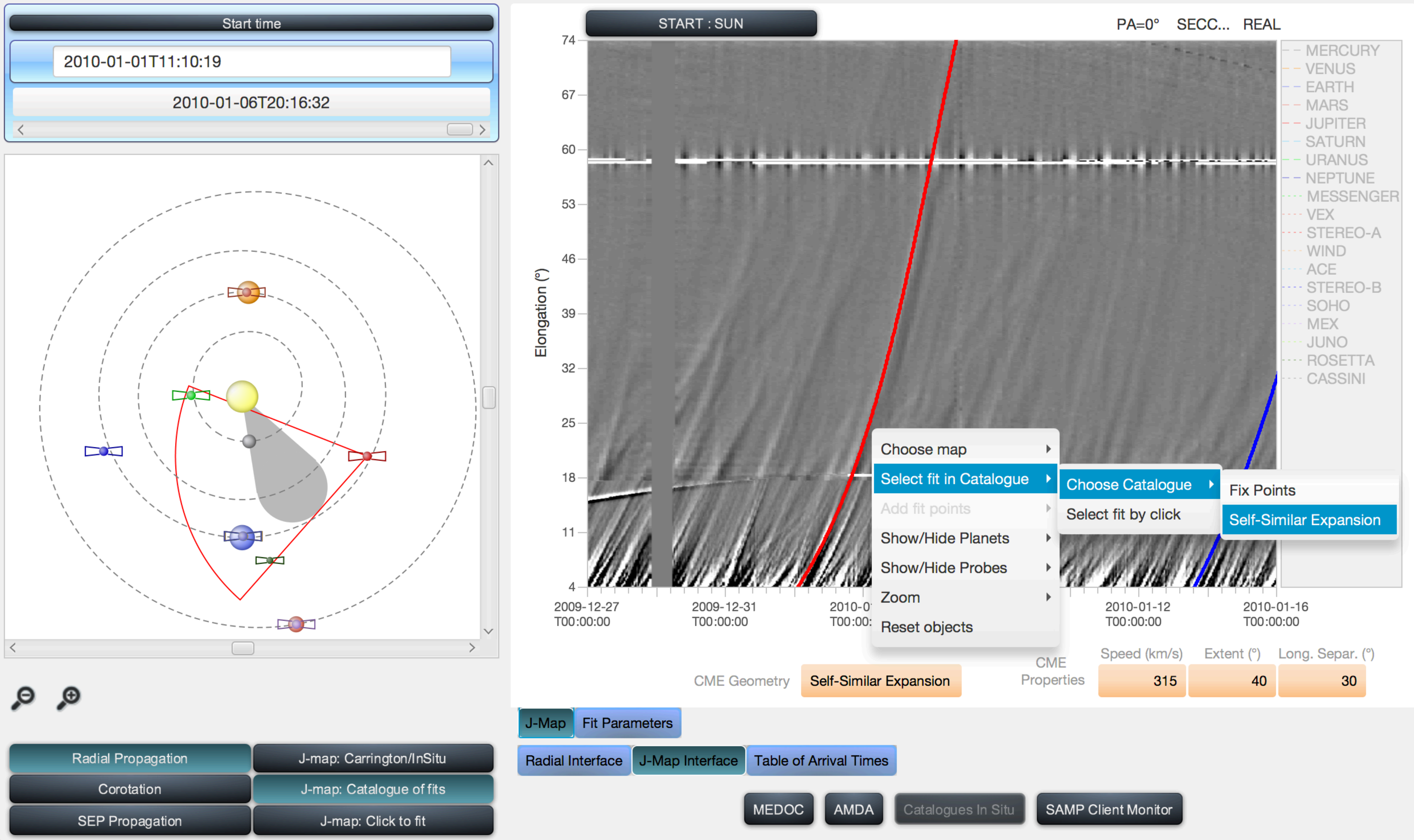
Target	t'	t'min(Δt)	t'max(Δt)	t'min(ΔV)	t'max(ΔV)	t'min(Δϕ)	t'max(Δϕ)	ϕEnd(t')-...
		(hrs)	(hrs)	(hrs)	(hrs)	(hrs)	(hrs)	(°)
SUN	2007-12-30T12:13:22	0	0	0	0	-38.07	38.07	8.78
Probes								
MESSEN...	2008-01-30T16:11:30	0	0	0	0	-38.07	38.07	352.06
VEX	2008-02-07T04:26:10	0	0	0	0	-38.07	38.07	134.56
STEREO-A	2008-02-02T12:31:54	0	0	0	0	-38.07	38.07	46.25
WIND	2008-01-31T22:51:22	0	0	0	0	-38.07	38.07	23.22
ACE	2008-01-31T22:20:41	0	0	0	0	-38.07	38.07	22.88
STEREO-B	2008-01-30T08:01:47	0	0	0	0	-38.07	38.07	357.78
SOHO	2008-01-31T22:02:47	0	0	0	0	-38.07	38.07	22.79
ROSETTA	2008-02-02T12:18:00	0	0	0	0	-38.07	38.07	43.11
CASSINI	2008-02-01T03:05:44	0	0	0	0	-38.07	38.07	45.84
Planets								
MERCURY	2008-01-31T18:55:17	0	0	0	0	-38.07	38.07	354.29
VENUS	2008-02-07T04:26:43	0	0	0	0	-38.07	38.07	134.57
EARTH	2008-01-31T23:53:42	0	0	0	0	-38.07	38.07	23.01
MARS	2008-02-03T08:24:41	0	0	0	0	-38.07	38.07	3.38
SATURN	2008-02-01T04:10:20	0	0	0	0	-38.07	38.07	45.86
URANUS	2008-02-03T02:48:47	0	0	0	0	-38.07	38.07	239.8
NEPTUNE	2008-02-09T16:09:23	0	0	0	0	-38.07	38.07	213.24

Given defined width, targets in red are impacted by CME

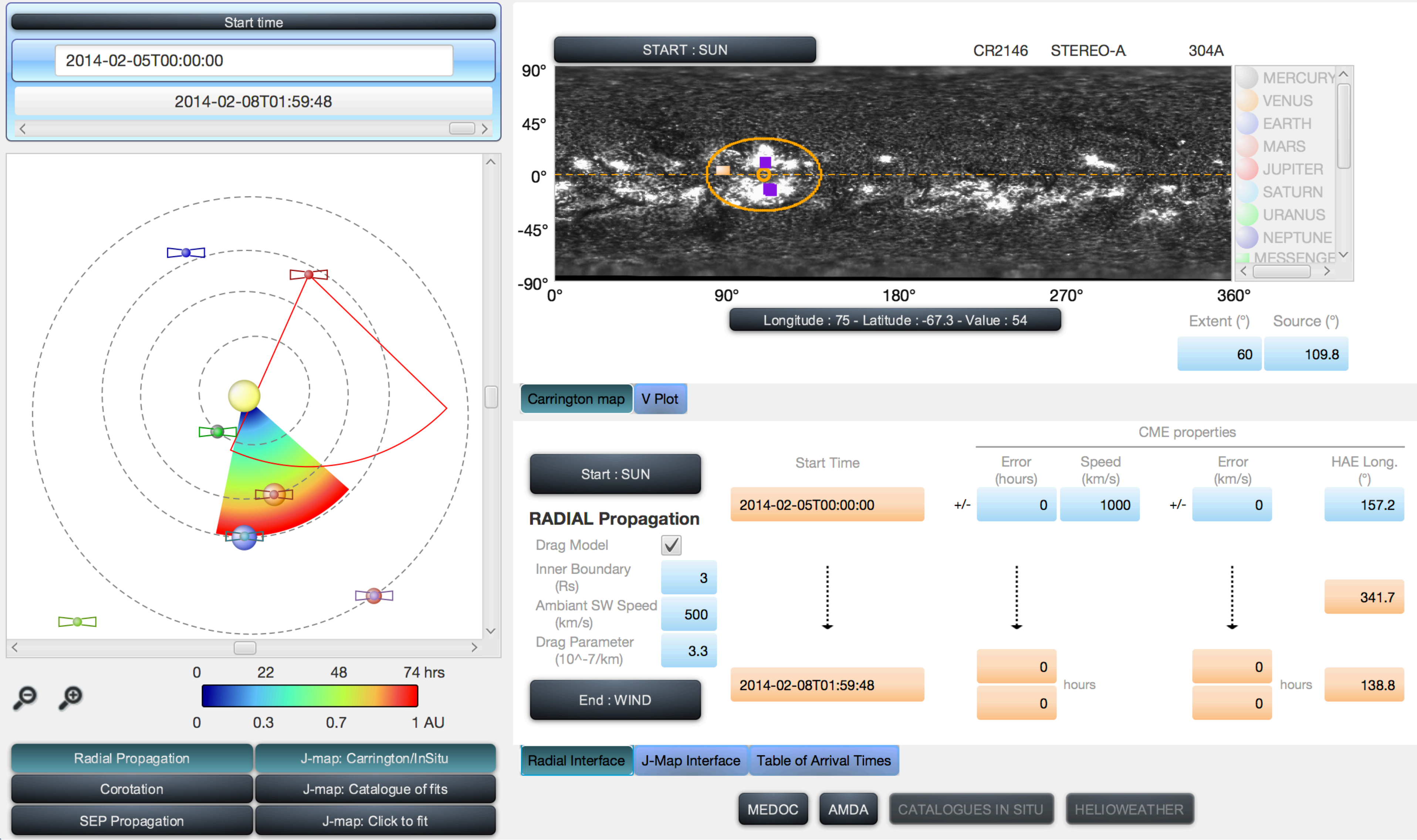
Corotation Interface | J-Map Interface | Table of Arrival Times

MEDOC | AMDA | Catalogues In Situ | SAMP Client Monitor

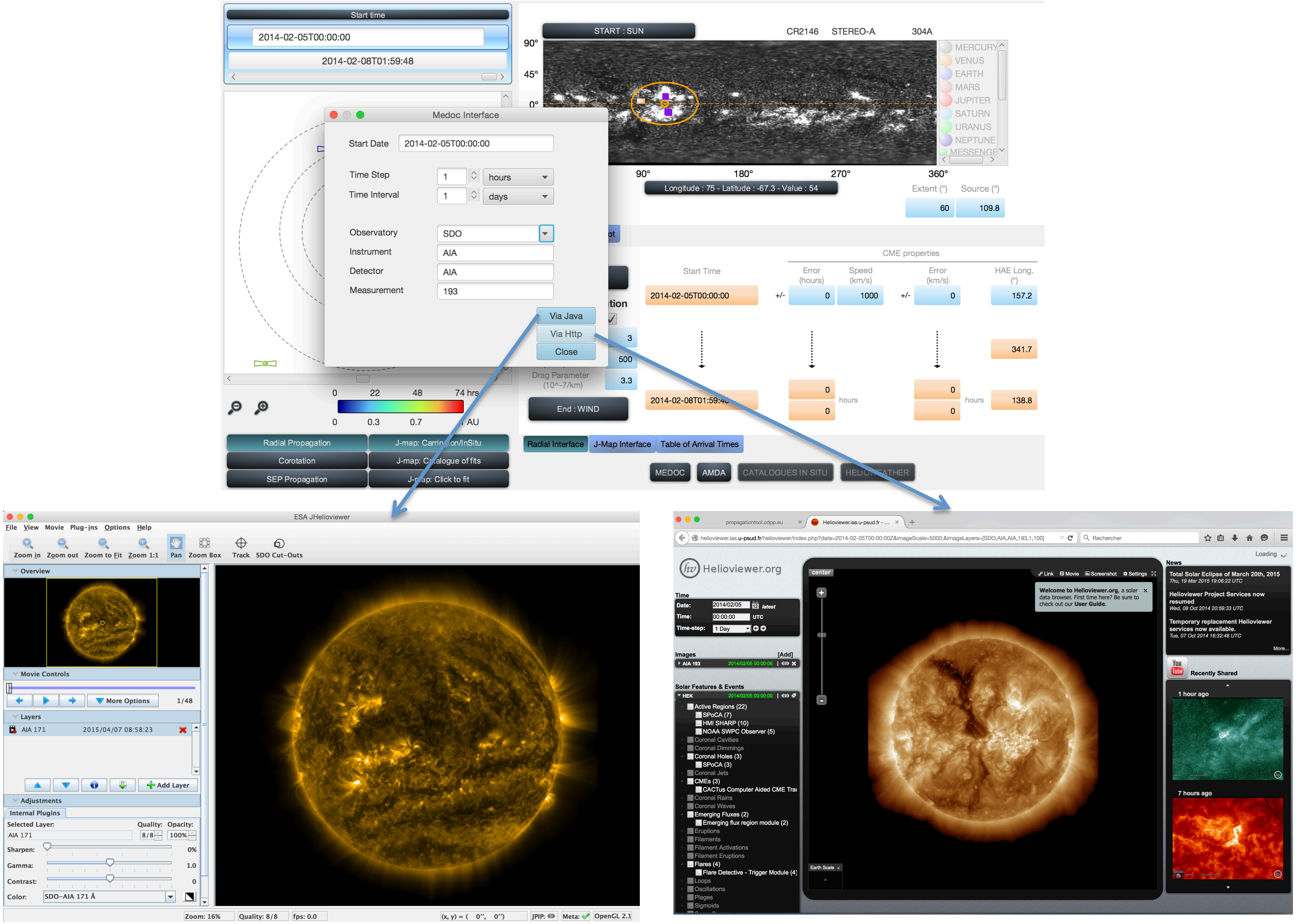
Inclusion of SSE



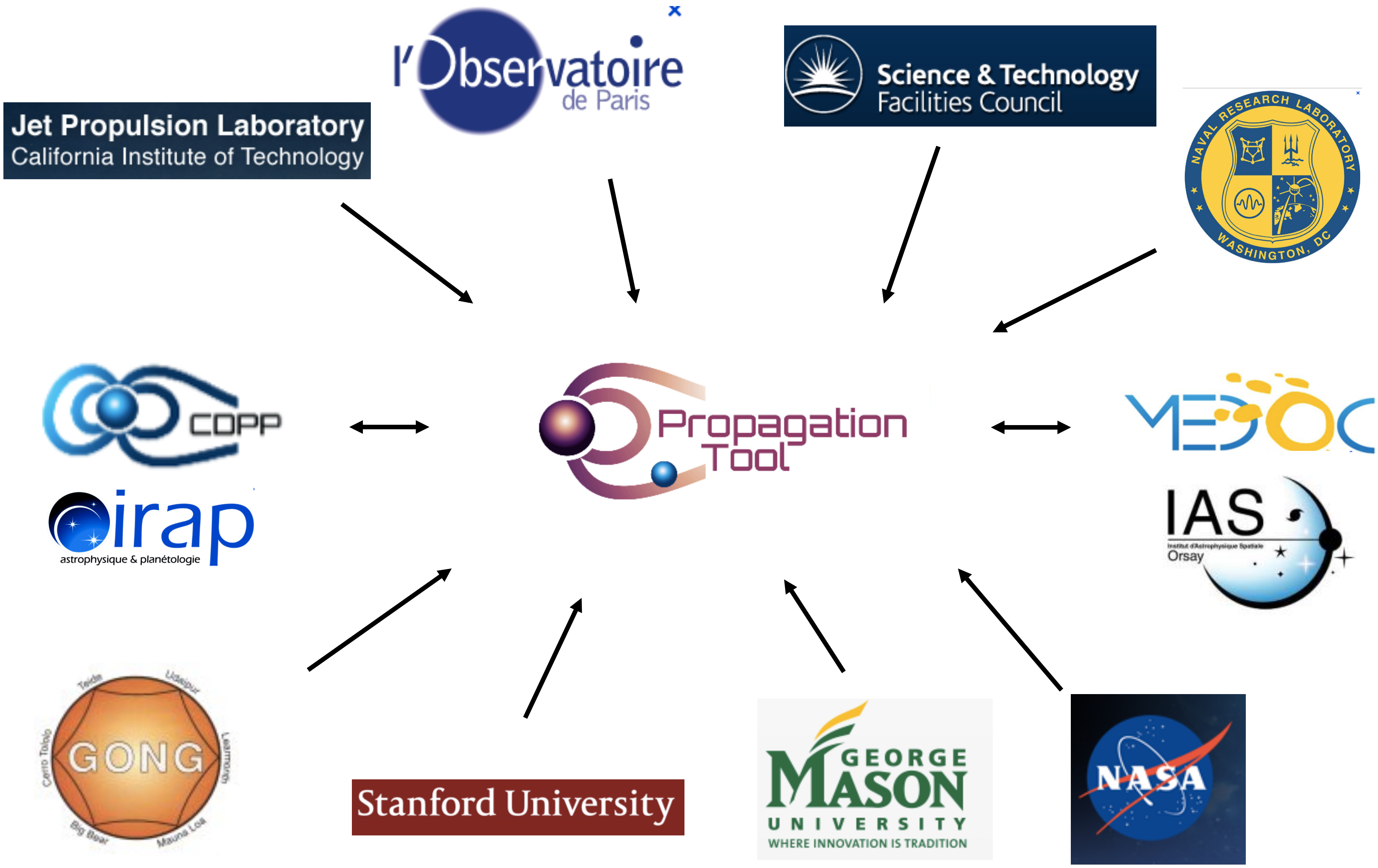
PROPAGATION TOOL



PROPAGATION TOOL



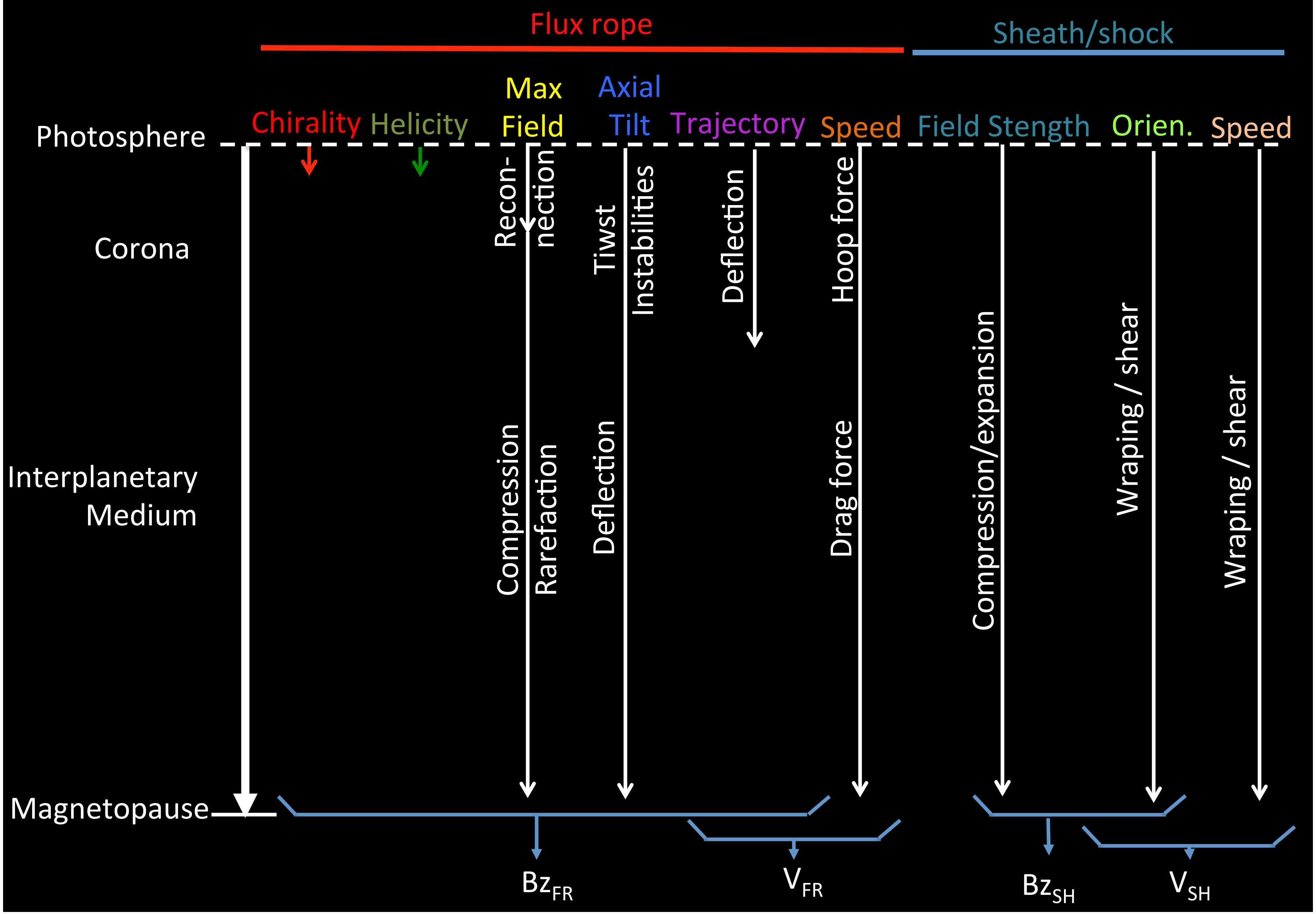
The tool retrieves data from several data centers and data repositories:



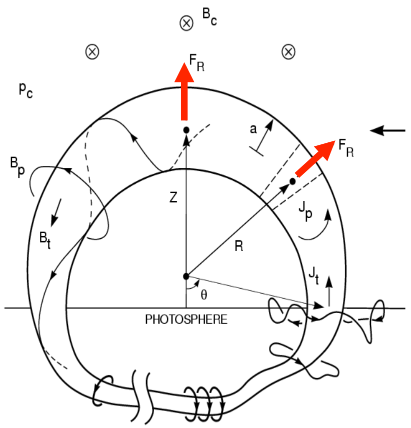
Why do CMEs erupt in the form of magnetic flux ropes?

Four main phases: buildup, instability, acceleration, and propagation (Forbes et al. 2006; Vrsnak 2008).

BUILDUP	INSTABILITY	ACCELERATION	PROPAGATION
New emerging Flux Progressive dispersion of the whole flux. The buildup of a very sheared field in the vicinity of PIL. The cancellation of flux at the PIL	The coronal magnetic configuration becomes unstable at some point during the slow evolution. Magnetic reconnection is probably involved for the transformation of the magnetic configuration. Configuration gets unstable when the FR reaches a height where the ambiant field is decreasing fast enough.	Laplace forces Gravity (/buoyancy)	Drag Compression/ Expansion


Flux rope
Sheath/shock
Photosphere
Corona
Interplanetary Medium
Magnetopause
Chirality
Helicity
Max Field
Axial Tilt
Trajectory
Speed
Field Stength
Orien.
Speed
Recon-nection
Compression
Rarefaction
Tiwst
Instabilities
Deflection
Deflection
Hoop force
Drag force
Compression/expansion
Wraping / shear
Wraping / shear
Bz$_{FR}$
V$_{FR}$
Bz$_{SH}$
V$_{SH}$

Chen 1996 formulated EFR model used a circular shape of the flux rope.

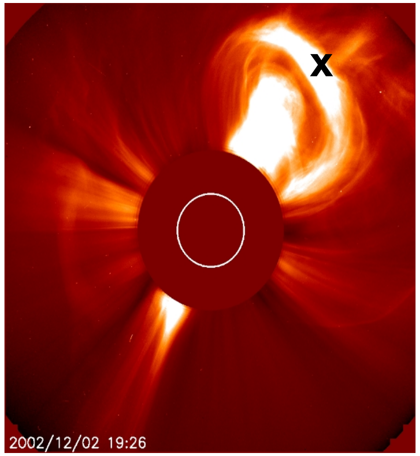


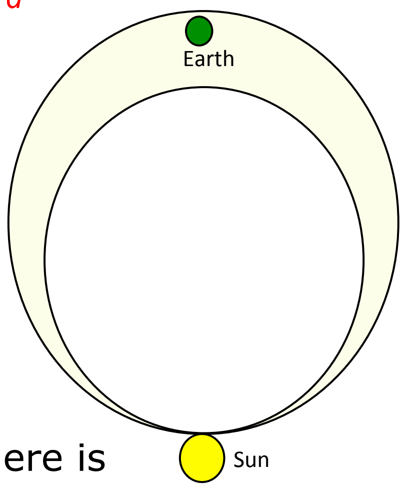
- Non-axisymmetric
- With fixed foot points
- Minor radial is variable
- Uniformmajor radius expands

The force density is given by: $\mathbf{f} = c^{-1}\mathbf{J}\mathrm{x}\mathbf{B} - \nabla p + \rho \nabla \phi_g$

$$F_R = \frac{I_t^2}{c^2 R}\left[\ln\left(\frac{8R}{a}\right) - 1 + \frac{\xi_i}{2} + \frac{1}{2}\beta_p - \frac{1}{2}\frac{B_t^2}{B_p^2} + 2\left(\frac{R}{a}\right)\frac{B_c}{B_p}\right] + F_g + F_d$$

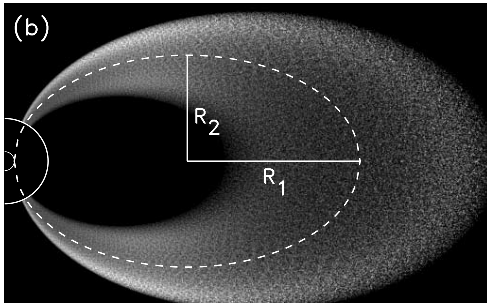
$$F_a = \frac{I_t^2}{c^2 a}\left[\frac{B_t^2}{B_p^2} - 1 + \beta_p\right] \qquad L = \frac{4\pi R}{c^2}\left[\ln\left(\frac{8R}{a}\right) - 2 + \frac{\xi}{2}\right]$$





So bright features represent high density of plasma along the line of sight. Here is the classical three-part CME structure (Hundhausen 1993)

This structure is interpreted as a magnetic flux rope.



Krall 2006 formulated a new form of EFR model used a elliptical shape of the flux rope.

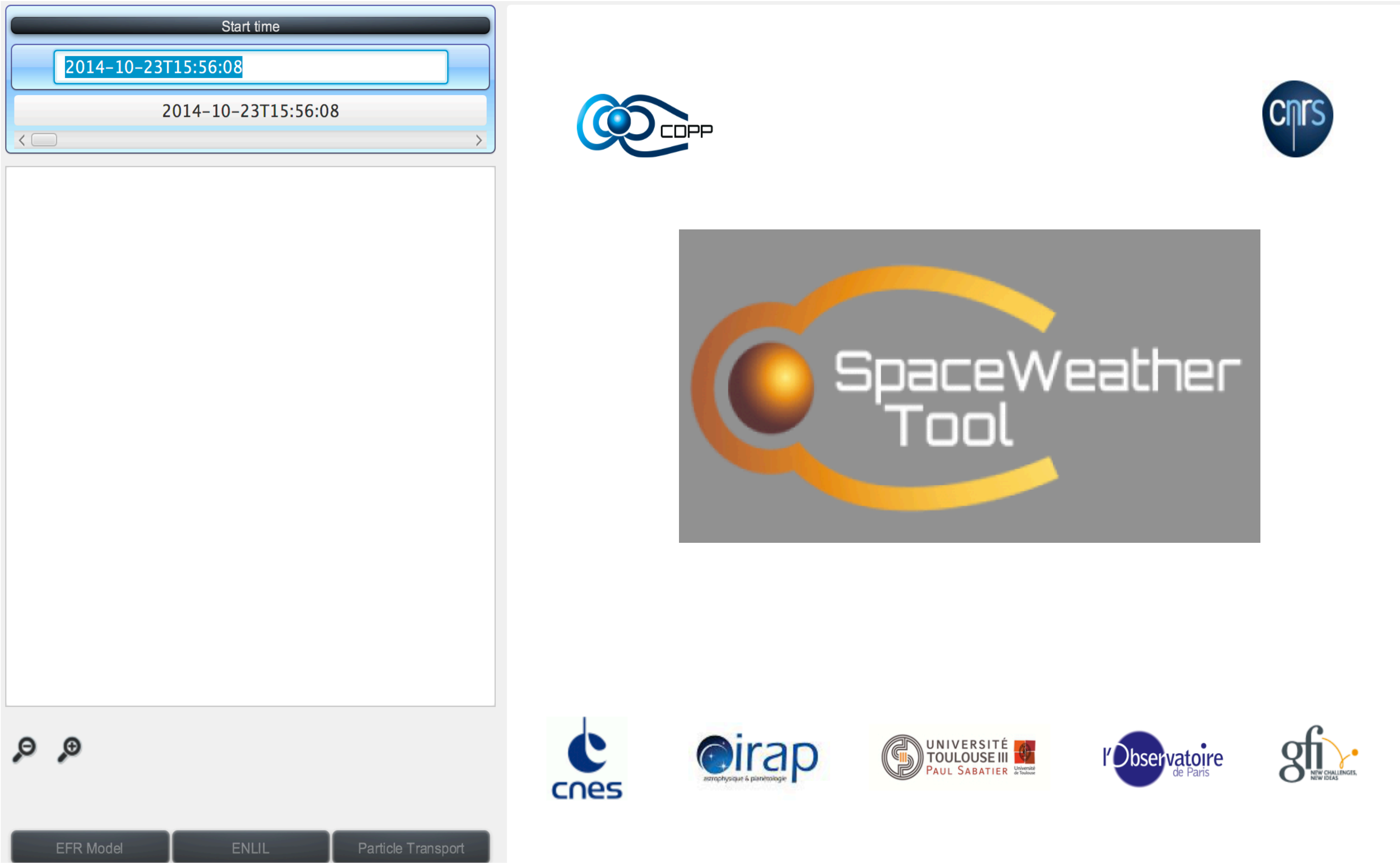
- Non-axisymmetric
- With fixed foot points
- Minor radial is variable
- CME is expanded as a ellipse with fix eccentricity .

$$\rho = \left(\frac{\rho_{a-}\rho_f}{\pi - \theta_f} \right) \left(\phi - \theta_f \right) + \rho_f$$

$$F_a = \frac{I_t^2}{c^2 a} \left[\frac{B_t^2}{B_p^2} - 1 + \beta_p \right] \qquad F_R = \frac{I_t^2 \kappa}{c^2} \left[\ln\left(\frac{8}{a\,\kappa} \right) + \frac{1}{2}\beta_p - \frac{1}{2}\frac{B_t^2}{B_{pa}^2} 2 \frac{1}{a\,\kappa} \frac{B_c}{B_{pa}} - 1 + \frac{\xi}{2} \right] + F_g + F_d \qquad \kappa = \frac{R_1}{R_2}$$

$$L = \frac{1}{c^2} \int_{\theta_f - \pi/2}^{\pi/2} ds \int_{s+\psi_0}^{s+2\pi-\psi_0} d\psi \frac{R^2{}_1 \cos(s)\cos(\psi) + R_2^2 \sin(s)\sin(\psi)}{\left[R_1^2 \left(\sin(s) - \sin(\psi) \right)^2 + R_2^2 \left(\cos(s) - \cos(\psi) \right)^2 \right]^{1/2}}$$

In a series of papers by Krall it was found that CMEs could be well fitted with an axisymmetric 3D ellipse (Krall et al. 2006a; Krall & St. Cyr 2006b; Krall 2007)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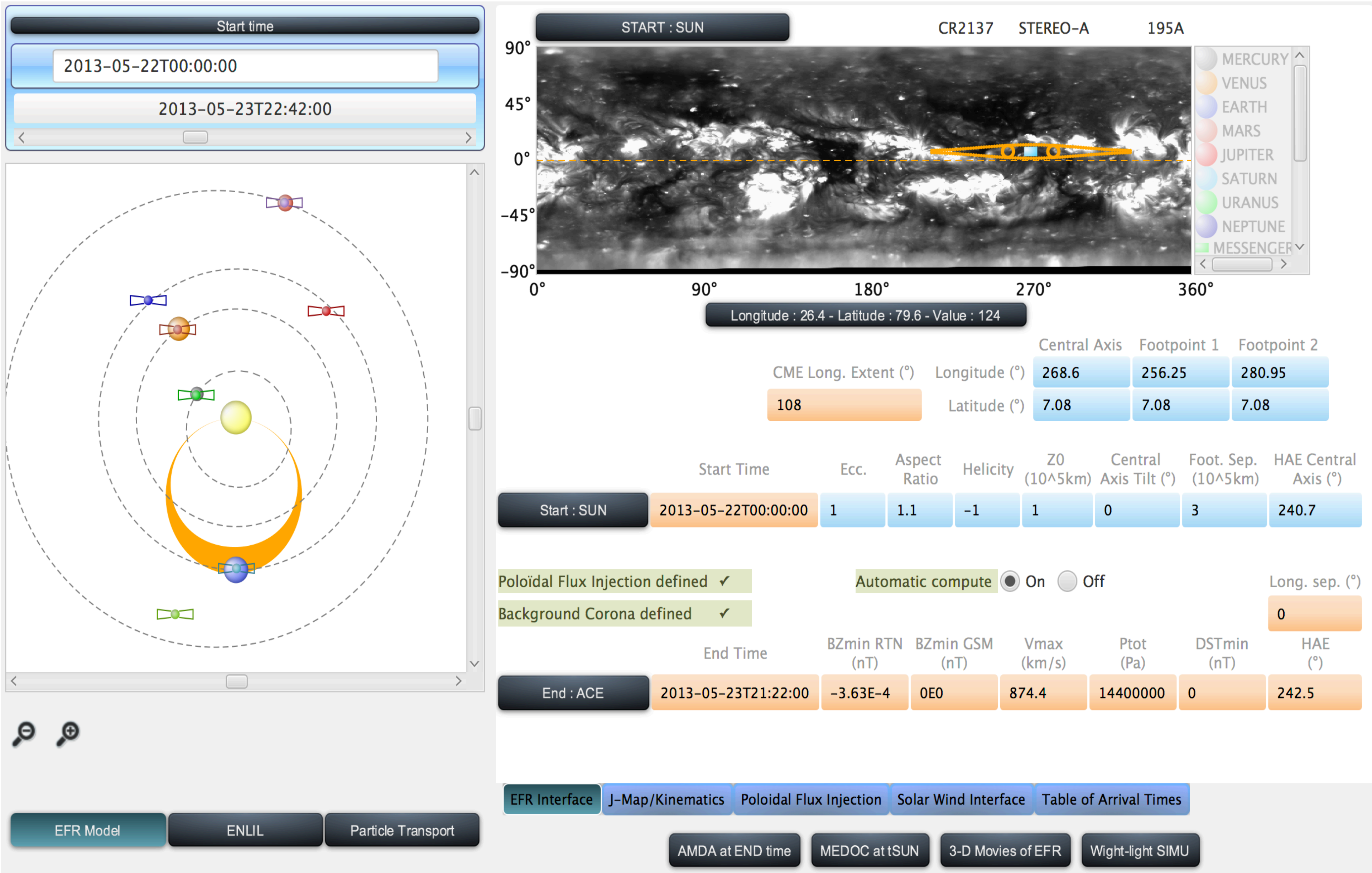
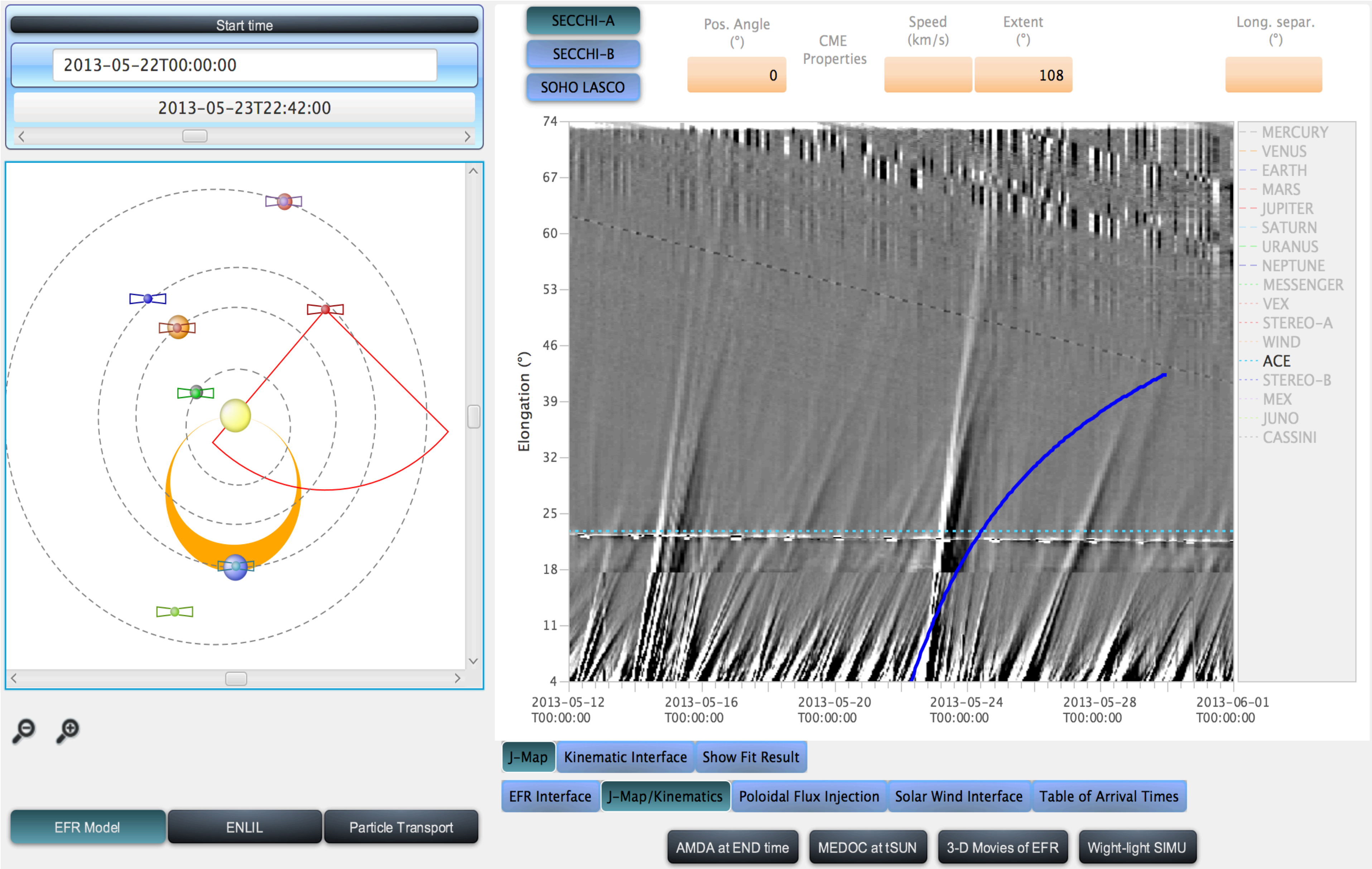
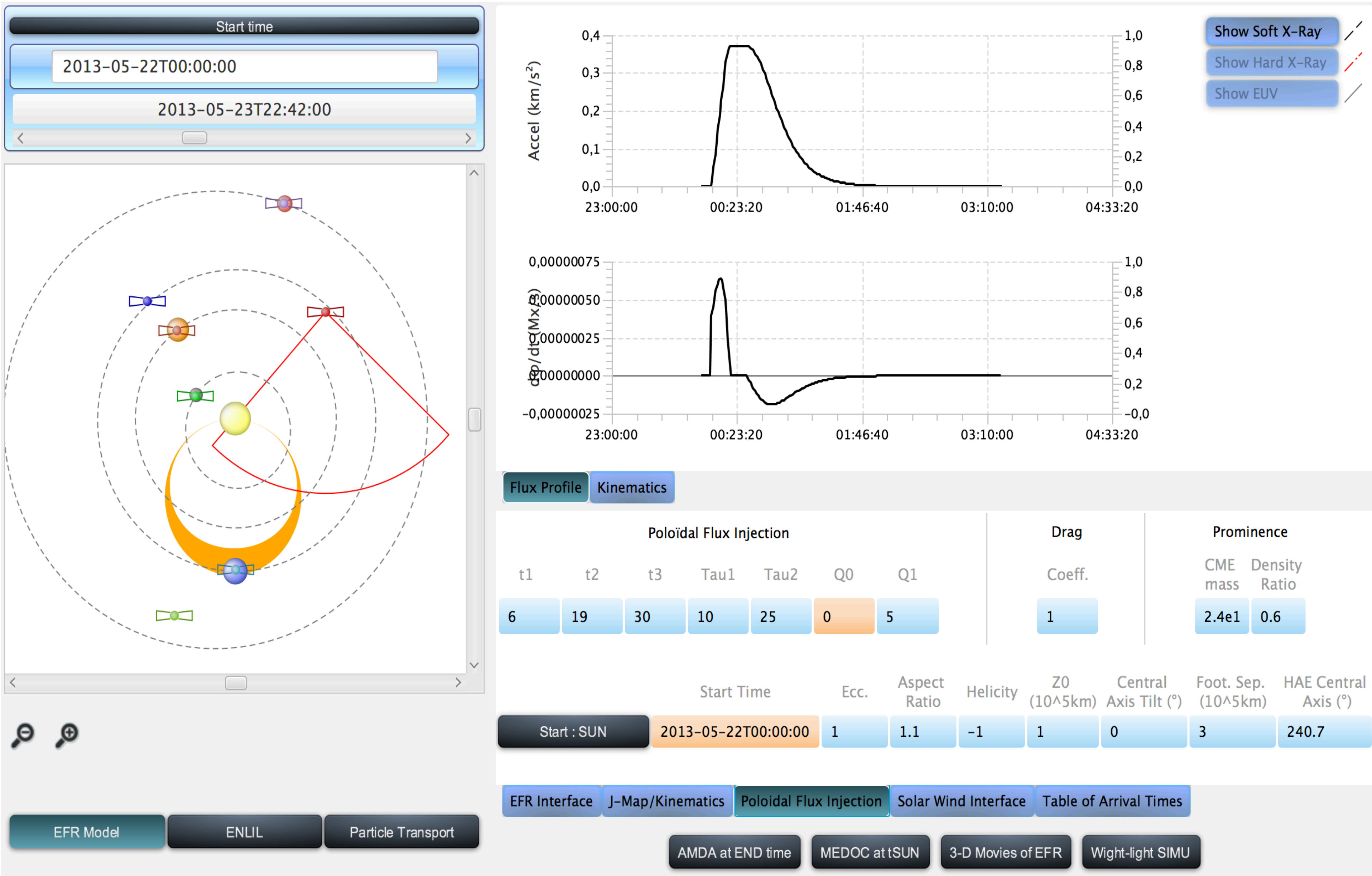
2014-10-23T15:56:08
2014-10-23T15:56:08
CDPP
SpaceWeather
Tool
EFR Model
ENLIL
Particle Transport


Start time
2013-05-22T00:00:00
2013-05-23T22:42:00
START : SUN
CR2137
STEREO-A
195A
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
MESSENGER
Longitude : 26.4 - Latitude : 79.6 - Value : 124
Central Axis
Footpoint 1
Footpoint 2
CME Long. Extent (°)
108
Longitude (°)
268.6
256.25
280.95
Latitude (°)
7.08
7.08
7.08
Start Time
Ecc.
Aspect Ratio
Helicity
Z0 (10^5km)
Central Axis Tilt (°)
Foot. Sep. (10^5km)
HAE Central Axis (°)
Start : SUN
2013-05-22T00:00:00
1
1.1
-1
1
0
3
240.7
Poloïdal Flux Injection defined ✓
Background Corona defined ✓
Automatic compute
On
Off
Long. sep. (°)
0
End Time
BZmin RTN (nT)
BZmin GSM (nT)
Vmax (km/s)
Ptot (Pa)
DSTmin (nT)
HAE (°)
End : ACE
2013-05-23T21:22:00
-3.63E-4
0E0
874.4
14400000
0
242.5
EFR Interface
J-Map/Kinematics
Poloidal Flux Injection
Solar Wind Interface
Table of Arrival Times
EFR Model
ENLIL
Particle Transport
AMDA at END time
MEDOC at tSUN
3-D Movies of EFR
Wight-light SIMU


Start time
2013-05-22T00:00:00
2013-05-23T22:42:00
SECCHI-A
SECCHI-B
SOHO LASCO
Pos. Angle (°)
0
CME Properties
Speed (km/s)
Extent (°)
108
Long. separ. (°)
Elongation (°)
74
67
60
53
46
39
32
25
18
11
4
2013-05-12 T00:00:00
2013-05-16 T00:00:00
2013-05-20 T00:00:00
2013-05-24 T00:00:00
2013-05-28 T00:00:00
2013-06-01 T00:00:00
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
MESSENGER
VEX
STEREO-A
WIND
ACE
STEREO-B
MEX
JUNO
CASSINI
J-Map
Kinematic Interface
Show Fit Result
EFR Interface
J-Map/Kinematics
Poloidal Flux Injection
Solar Wind Interface
Table of Arrival Times
EFR Model
ENLIL
Particle Transport
AMDA at END time
MEDOC at tSUN
3-D Movies of EFR
Wight-light SIMU

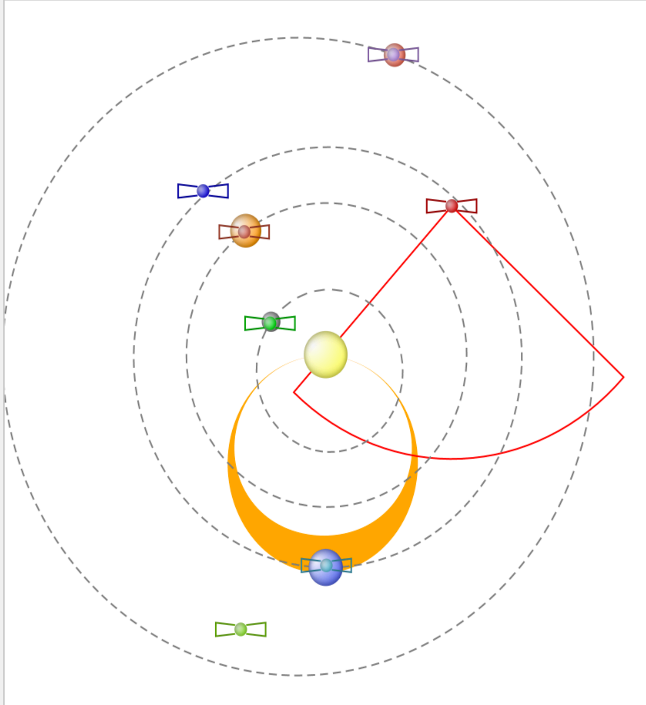


Start time
2013-05-22T00:00:00
2013-05-23T22:42:00
Show Soft X-Ray
Show Hard X-Ray
Show EUV
Accel (km/s²)
0,4
0,3
0,2
0,1
0,0
1,0
0,8
0,6
0,4
0,2
0,0
23:00:00
00:23:20
01:46:40
03:10:00
04:33:20
0,00000075
0,00000050
0,00000025
0,00000000
-0,00000025
-0,0
Flux Profile
Kinematics
Poloïdal Flux Injection
Drag
Prominence
t1
t2
t3
Tau1
Tau2
Q0
Q1
Coeff.
CME mass
Density Ratio
6
19
30
10
25
0
5
1
2.4e1
0.6
Start Time
Ecc.
Aspect Ratio
Helicity
Z0 (10^5km)
Central Axis Tilt (°)
Foot. Sep. (10^5km)
HAE Central Axis (°)
Start : SUN
2013-05-22T00:00:00
1
1.1
-1
1
0
3
240.7
EFR Interface
J-Map/Kinematics
Poloidal Flux Injection
Solar Wind Interface
Table of Arrival Times
EFR Model
ENLIL
Particle Transport
AMDA at END time
MEDOC at tSUN
3-D Movies of EFR
Wight-light SIMU

Start time

2013-05-22T00:00:00

2013-05-23T22:42:00



Target	tmin	tmax	|φCME(tSUN... φTarget(tSU...	Distance Sun	φCME(tSUN)	φTARGET(t...
			(°)	(AU)	(°)	(°)
Probes						
MESSENGER			232.86	0.318	240.72	
VEX			214.25	0.7194	240.72	
STEREO-A			137.06	0.9599	240.72	
ACE	2013-05-23T2...	2013-05-24T0...	0	1.0025	240.72	242.49
STEREO-B			218.8	1.0031	240.72	
MEX			166.85	1.4669	240.72	
JUNO	2013-05-24T1...	2013-05-25T0...	342.03	1.3915	240.72	224.31
CASSINI			338.04	9.8234	240.72	
Planets						
MERCURY			232.86	0.318	240.72	
VENUS			214.25	0.7194	240.72	
EARTH	2013-05-23T2...	2013-05-24T0...	0.09	1.0122	240.72	242.64
MARS			166.85	1.4669	240.72	
JUPITER			205.16	5.1108	240.72	
SATURN			338.04	9.8279	240.72	
URANUS			128.16	20.0491	240.72	
NEPTUNE			92.46	29.9862	240.72	

Given defined width, targets in red are impacted by CME

EFR Interface | J-Map/Kinematics | Poloidal Flux Injection | Solar Wind Interface | Table of Arrival Times

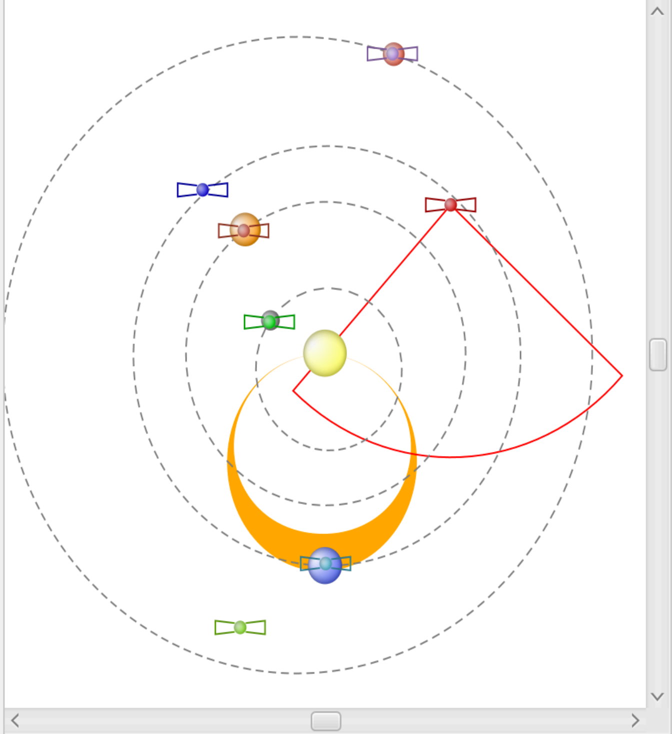
EFR Model | ENLIL | Particle Transport

AMDA at END time | MEDOC at tSUN | 3-D Movies of EFR | Wight-light SIMU

Start time

2013-05-22T00:00:00

2013-05-23T22:42:00



Target	tmin	tmax	|φCME(tSUN... φTarget(tSU...	Distance Sun	φCME(tSUN)	φTARGET(t...
			(°)	(AU)	(°)	(°)
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Given defined width, targets in red are impacted by CME

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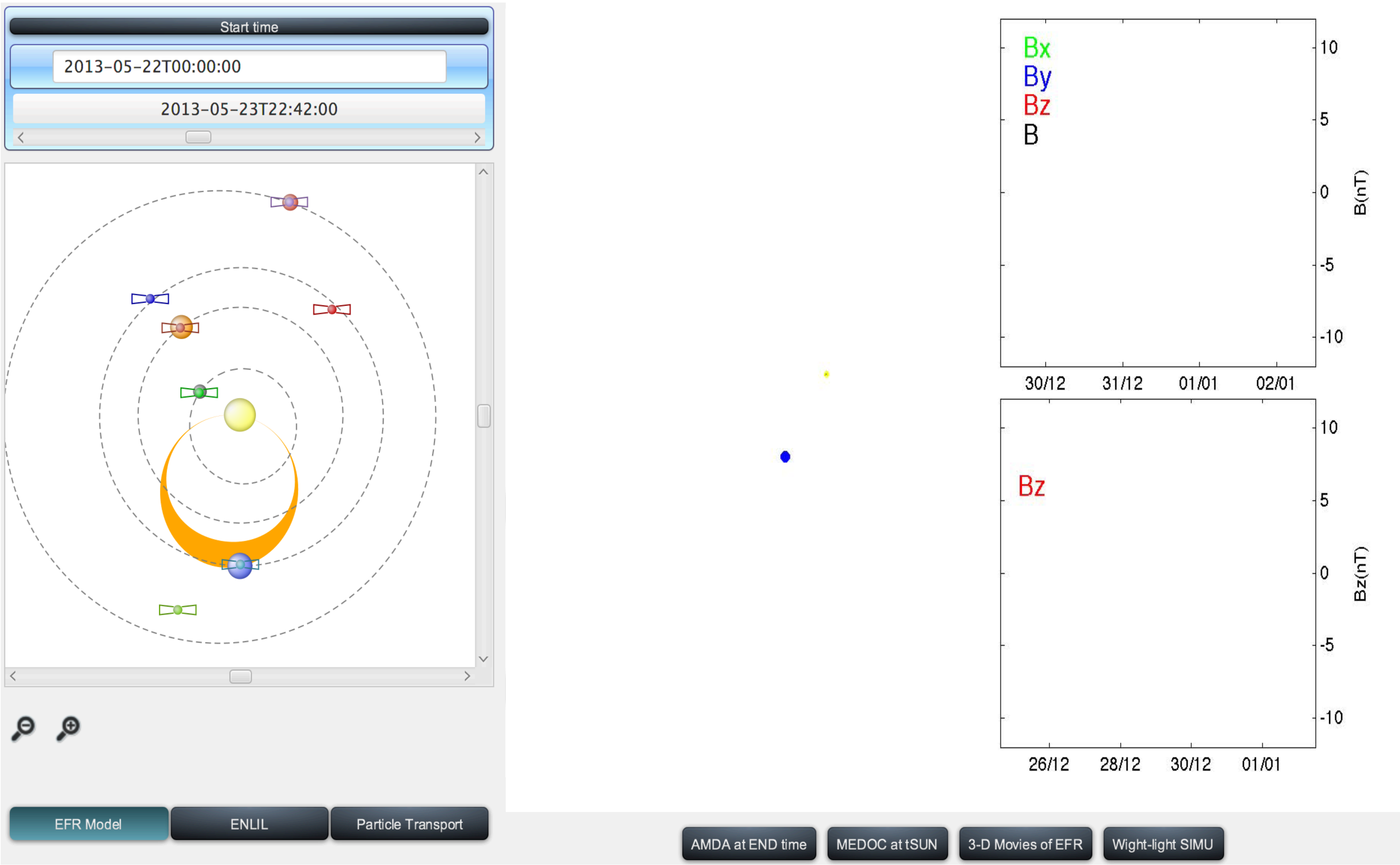
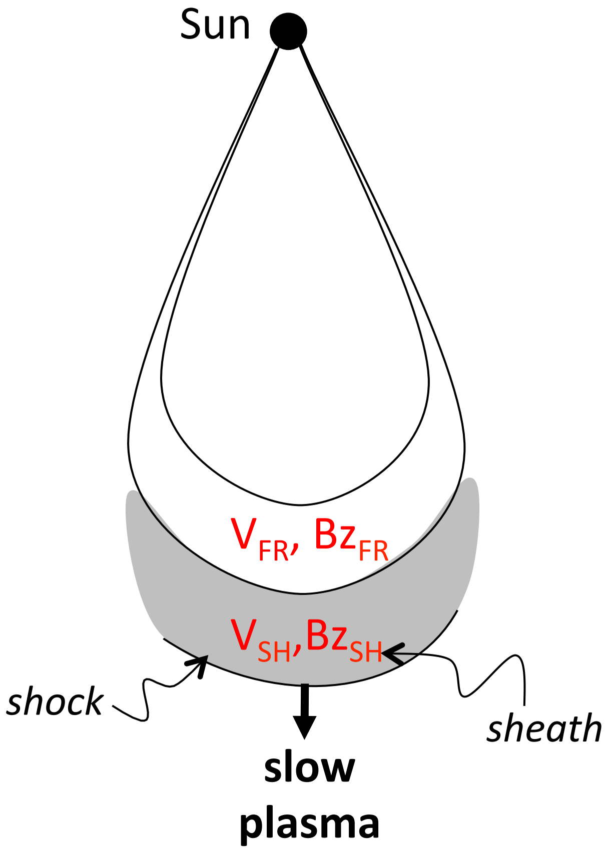
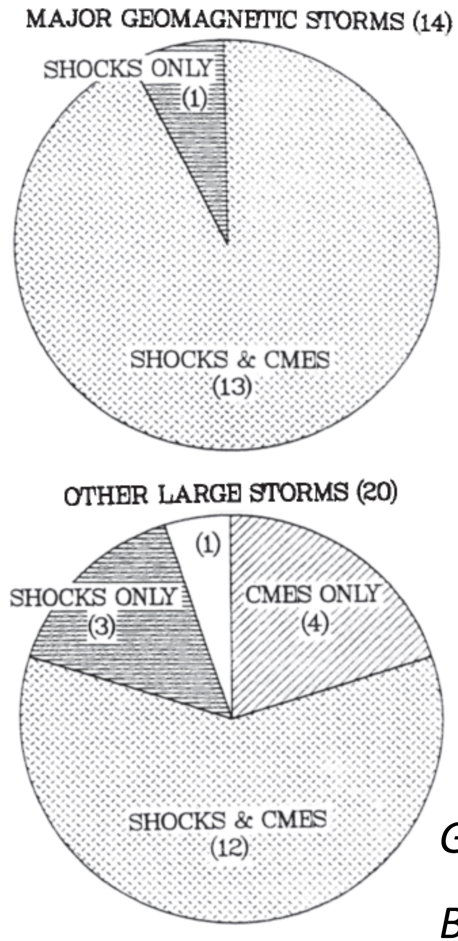

Start time
2013-05-22T00:00:00
2013-05-23T22:42:00
Bx
By
Bz
B
10
5
0
-5
-10
B(nT)
30/12
31/12
01/01
02/01
Bz
10
5
0
-5
-10
Bz(nT)
26/12
28/12
30/12
01/01
EFR Model
ENLIL
Particle Transport
AMDA at END time
MEDOC at tSUN
3-D Movies of EFR
Wight-light SIMU

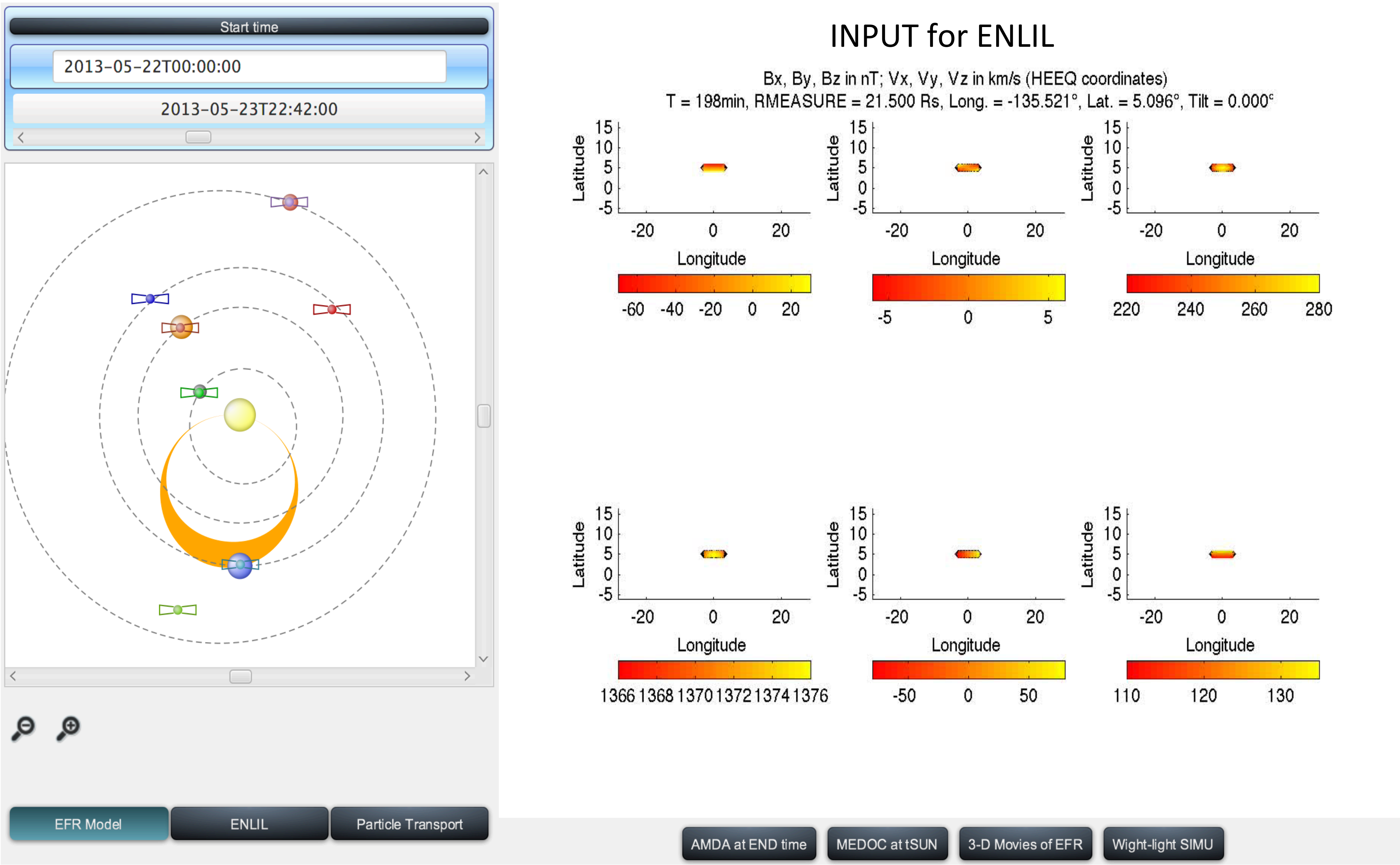




Gosling et al. [1990]

Burlaga et al. [2003]
Tsurutani et al. [1992]
Etc.

→ **Shocks and sheaths largely impact geo-effectiveness**


Start time
2013-05-22T00:00:00
2013-05-23T22:42:00
INPUT for ENLIL
Bx, By, Bz in nT; Vx, Vy, Vz in km/s (HEEQ coordinates)
T = 198min, RMEASURE = 21.500 Rs, Long. = -135.521°, Lat. = 5.096°, Tilt = 0.000°
Latitude
Longitude
-60 -40 -20 0 20
-5 0 5
220 240 260 280
1366 1368 1370 1372 1374 1376
-50 0 50
110 120 130
EFR Model
ENLIL
Particle Transport
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Wight-light SIMU