Coronal Mass Ejection Forecasting Version Description

UPOS-A63-06

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Version 1.0

By
Barry J. LaBonte
Linda M. Burke
Bruce A. Toth

Table of Contents

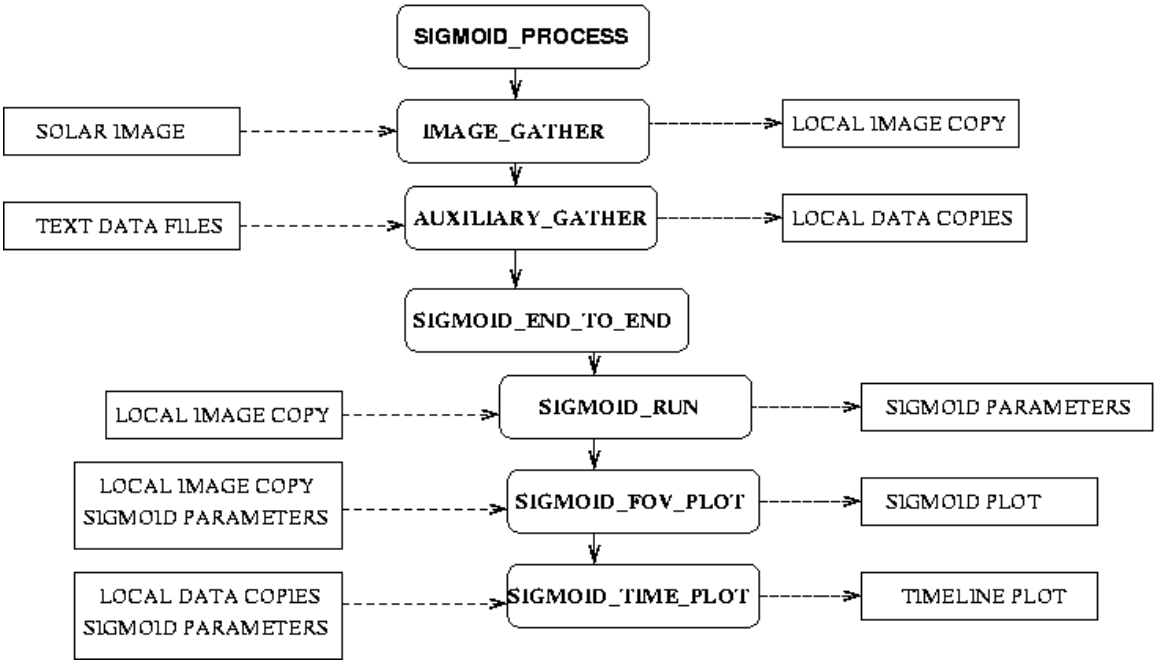
1.INTRODUCTION

1.1 Overview

The primary purpose of the Coronal Mass Ejection Forecasting software is to provide the capability to identify solar active regions with sigmoidal, S-shaped coronal structure. Sigmoidal structure is generally apparent hours to days before the occurrence geoeffective events from the active region. The purpose of the Coronal Mass Ejection Forecasting project is to identify sigmoidal regions using an automated, objective process.

1.2 System Overview

The system architecture is based on software that is currently used for similar purposes at JHU/APL. Figure 1 shows a diagram of the architecture and data flow.



The Coronal Mass Ejection Forecasting process searches for and gathers previously unprocessed solar coronal images. Images are examined for sigmoidal structure, by searching for intensity contours with an “S” shape, or its mirror image. If sigmoids are found, a summary of their properties is saved. A display version of a solar image with a sigmoid is produced, showing the sigmoid outline. The process also gathers auxiliary data on heliospheric and geospace conditions. The process plots a timeline of activity over the latest week, including any sigmoids.

A shell script controls the entire process, starting the various steps in the process in turn. The script is designed to run automatically by the system at times that can be locally determined. A user views the various output images with a Web browser.

2. REFERENCED DOCUMENTS

Canfield, R.C., H.S. Hudson and D.E. McKenzie, “Sigmoidal Morphology and Eruptive Solar Activity”, 1999, *Geophys. Res. Lett*., **26**, 627.

Glover, A., N.D.R. Ranns, L.K. Harra, and J.L. Culhane, “The Onset and Association of CMEs with Sigmoidal Active Regions”, 2000, *Geophys. Res. Lett*., **27**, 2161.

Pevtsov, A.A. and R.C. Canfield, “Solar magnetic fields and geomagnetic events”, 2001, *J. Geophys. Res*., **106**, 25191.

3. VERSION DESCRIPTION

3.1 Inventory of material released

The Coronal Mass Ejection Forecasting software is being released via network transfer.

The documentation that supports this version is listed below and has been delivered with the installation of the system.

- Coronal Mass Ejection Forecasting Functional Requirements Document, UPOS-A63-02, Version 1.0, Barry J. Labonte, Linda. M. Burke, Bruce A. Toth, 30 May 2003

- Coronal Mass Ejection Forecasting Design Document, UPOS-A63-01, Version 1.0, Linda M. Burke, Barry J. Labonte, Bruce A. Toth, 30 May 2003

- Test Plan for Coronal Mass Ejection Forecasting, UPOS-A63-04, Version 1.0, Linda M. Burke, Barry J. Labonte, Bruce A. Toth, 30 May 2003

- Coronal Mass Ejection Forecasting Test Report, Version 1.0, L. P. Butler, TBD

- Coronal Mass Ejection Forecasting User’s Guide, UPOS-A63-05, Version 1.0, Barry J. Labonte, Linda M. Burke, Bruce A. Toth, 30 May 2003

- Coronal Mass Ejection Forecasting Support Plan, UPOS-A63-03, Version 1.0, Linda M. Burke, Barry J. Labonte, Bruce A. Toth, 30 May 2003

- Coronal Mass Ejection Forecasting Software Version Description, UPOS-A63-06, Version 1.0, Barry J. Labonte, Linda M. Burke, Bruce A. Toth, 30 May 2003

3.2 Inventory of software components

Appendix B lists the software components that comprise Version 1.0 of the Coronal Mass Ejection Forecasting software system.

3.3 Changes installed

This is the initial version of the software.

3.4 Related Documents

All documents pertinent to Version 1.0 of the Coronal Mass Ejection Forecasting software system are included in the release.

3.5 Install instructions

A Unix system administrator should install the Coronal Mass Ejection Forecasting codes and related software. The necessary steps are listed here.

Install SolarSoft

The sigmoid codes use a large number of publicly available IDL procedures that are part of the SolarSoft distribution. Verify that SolarSoft is installed on the target machine, or arrange for its installation. SolarSoft is described at http://www.lmsal.com/solarsoft/ssw_whatitis.html. The other IDL procedures used by the Coronal Mass Ejection Forecasting process are listed in Appendix B.

Define site-dependent parameters

The Coronal Mass Ejection Forecasting codes define several environment variables in the setup file *site_dependent* which can be found in the $DIR_SIGMOID/setup directory. Sourcing this file enables both interactive and automatic operation of the codes. In addition, the binaries must be linked into the user's path. The list of environment variables is given in the following table. The top directory of the tree containing the Coronal Mass Ejection Forecasting codes and data is defined as an environment variable, DIR_SIGMOID. The other environment variables define the operation of the SolarSoft code package.

Environment Variable	Purpose
DIR_SIGMOID	Directory path to the location of the sigmoid tree.
SIGMOID_IMAGE_TYPE	Instrument acronym of the source of solar coronal images.
SSW_INSTR	List of SolarSoft packages to include
solar	Directory path to one level above the location of the SolarSoft software
SSW	Set to $solar/ssw to locate the SolarSoft software
SSWDB	Set to $solar/sswdb to locate of the SolarSoft database
HESSI_PATH	Set to $SSW/hessi to locate the HESSI package
ssw_quiet	Set to 1 to eliminate unneeded messages
sswidl	Set to $SSW/gen/setup/setup.ssw to locate the SolarSoft executable

The present list of SolarSoft packages to include is: “eit lasco mdi sxt bcs hxt wbs trace hessi stereo binaries chianti andril spex xray goes mees nso”. The choice for SIGMOID_IMAGE TYPE is presently SXI, since the GOES-12 SXI is in operation.

APPENDICES

A. Acronyms and Abbreviations

AACGM	Attitude Adjusted Corrected Geomagnetic
ACE	Advanced Composition Explorer
AFCCC	Air Force Combat Climatology Center
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AFSPACECOM	Air Force Space Command
AFSWC	Air Force Space Weather Center
AFWA	Air Force Weather Agency
AFWIN	Air Force Weather Information Network
AF/XOW	Air Force Director of Weather
APL	Applied Physics Laboratory of Johns Hopkins University
ASCII	American Standard Code for Information Interchange
ASPAM	Atmospheric Slant Path Analysis Model
AVHRR	Advanced Very High Resolution Radiometer
AVN	Aviation Model
AVO	Alaska Volcano Observatory
BATS	Biosphere-Atmosphere Transfer Scheme
CARMA	Community Aerosol Research Model from Ames/NASA
CLASS	Canadian Land Surface Scheme
CME	Coronal Mass Ejections
COE	Common Operating Environment
DII	Defense Information Infrastructure
DMSP	Defense Meteorological Satellite Program
Dst	Disturbance, storm
ECMWF	European Center for Medium-Range Weather Forecasts
EIT	Extreme Ultraviolet Imaging Telescope
EVA	Extravehicular Activities
FAC	Field Aligned Currents
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FSL	Forecast Systems Laboratory
FTP	File Transfer Protocol
GI	Geophysical Institute
GIC	Ground Induced Currents
GIF	Graphic Interchange Format
GIT	Georgia Institute of Technology
GMT	Generic Mapping Tools
GOLD	Geophysical On-Line Data
GOES	Geostationary Operational Environment Satellite
GRIB	Gridded Binary
GSE	Geocentric Solar-Ecliptic
GSFC	Goddard Space Flight Center

HLBL	High Latitude Boundary Layer
IDL	Interactive Data Language
IMF	Interplanetary Magnetic Field
ISS	International Space Station
JHU	Johns Hopkins University
Kp	Planetary Index of Geomagnetic Activity
LAN	Local Area Network
LAPS	Local Analysis and Prediction System
LASCO	Large Angle Spectroscope Coronagraph
LEO	Low-attitude Earth Orbit
LSM	Land Surface Model
MATCH	Model of Atmospheric Transport and Chemistry
MeV	Million Electron Volts
MM5	Fifth Generation Mesoscale Model
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
netCDF	Network Common Data Form
NGDC	National Geophysical Data Center
NGM	Nested Grid Forecast Model
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction System
NRL	Naval Research Laboratory
NWP	Numerical Weather Prediction
OWS	Operational Weather Squadron
PACE	Polar Anglo-American Conjugate Experiment
PBL	Planetary Boundary Layer
PCA	Polar Cap Absorption
PFRR	Poker Flat Research Range
PNG	Portable Network Graphics
RBE	Radiation Belt Environment
SAA	South Atlantic Anomaly
SABER	Sounding of the Atmosphere using Broadband Emission Radiometry
SD	Space Department of the Applied Physics Laboratory
SDFM	Surface Dust Flux Model
SDP	Software Development Plan
SEC	Space Environment Center
SEE	Solar EUV Experiment
SEON	Solar Electro-optical Observing Network
SEP	Solar Energetic Particles
SFOC	Space flight Operations Center
SOHO	Solar and Heliospheric Observatory
SPE	Solar Particle Event
STP	Solar Terrestrial Physics
SWOC	Space Weather Operations Center (Offutt)
SWXS	Space Weather Squadron

SXI	Soft X-ray Imager
Tcl	Tool Command Language
Tk	Toolkit
Tix	Tk Interface Extension
UAF	University of Alaska, Fairbanks
UCAR	University Corporation for Atmospheric Research
UCB	University of Colorado, Boulder
UPOS	University Partnering for Operational Support
UTC	Coordinated Universal Time
WDC	World Data Center
WF	Weather Flight
WMO	World Meteorological Organization
XDR	External Data Representation

B. Inventory of Software contents of Version 1.0

The sigmoid codes include shell scripts that run directly under the Unix system and IDL procedures that run under IDL.

Shell script name	Purpose
run_sigmoid	Sets up environment variable and calls sigmoid process.

Perl script name	Purpose
sigmoid_process	Runs entire sigmoid data gathering and finding process.
get_cme_image.pl	Gathers latest solar coronal images, if any.
get_auxiliary_gather.pl	Gathers auxiliary solar, heliospheric, and geospace data.

IDL procedure name	Purpose
Sigmoid specific	
eit_gif2fits.pro	Converts EIT GIF images to FITS files, with simple headers.
find_ar.pro	Given a position on the solar disk, identifies it with the nearest active region.
sigmoid_corona.pro	For a solar coronal image, sets up for sigmoid finding.
sigmoid_end_to_end.pro	Main for running sigmoid processing.
sigmoid_find.pro	Given an image, finds sigmoidal contours.
sigmoid_fov_plot.pro	Plots sigmoid on image, writes image file.
sigmoid_id.pro	Decides whether a contour is a sigmoid based on curvature method.
sigmoid_run.pro	Runs sigmoid finder on a set of files.
sigmoid_start.pro	Oversees processing, plotting, file organization of the IDL codes.
sigmoid_time_plot.pro	Plots timeline of sigmoids, X-ray flares, other auxiliary data.
xy2kappa.pro	Converts x,y positions of a figure into a curvature vs arc length.

IDL procedure name	Purpose
Mees Solar Observatory	
ace_mag_read.pro	Read ACE magnetometer text files.
ace_sis_read.pro	Read ACE energetic particles text files.
lasco_cme_read.pro	Read LASCO CME list text files.
latcmd2loc.pro	Converts solar latitude, central meridian distance to position string.

loc2latcmd.pro	Converts solar position string to latitude, central meridian distance.
sec_events_read.pro	Read SEC flare events text files.
sec_kp_read.pro	Read SEC Kp index text files.
sec_regions_read.pro	Read SEC active region text files.

Directory /project/upos/dust/CME			
CME_software uninstall.pl	840	SXI	1024
ACE	1024	bin	512
EIT	512	html	512
LASCO	512	idl	1024
SEC	1024	setup	512
Total of 9 directories and 2 files, 7496 bytes.			
Directory /project/upos/dust/CME/bin			
get_auxiliary_data.pl	2577	run_sigmoid.pl	149
get_cme_image.pl	763	sigmoid_process	611
Total of 4 files, 4100 bytes.			
Directory /project/upos/dust/CME/html			
images	1024		
Total of 1 directory, 1024 bytes.			
Directory /project/upos/dust/CME/idl			
SIGMOID_start	224	sec_regions_read.pro	3779
ace_mage_read.pro	1687	sigmoid_corona.pro	3346
ace_sis_read.pro	1589	sigmoid_end_to_end.pro	144
eit_gif2fits.pro	1844	sigmoid_find.pro	4323
find_ar.pro	1614	sigmoid_fov_plot.pro	2669
lasco_cme_read.pro	2121	sigmoid_id.pro	3077
latcmd2lob.pro	827	sigmoid_run.pro	3988
loc2latcmd.pro	727	sigmoid_start.pro	3381
sec_events_read.pro	3605	sigmoid_time_plot.pro	12497
sec_kp_read.pro	1661	xy2kappa.pro	1219
Total of 20 files, 54322 bytes.			
Directory /project/upos/dust/CARMA/setup			
Site_dependent	409		
Total of 1 files, 409 bytes.			
Grand total of 10 directories, 28 files, 67 MB.			

C. Input data

The specific Web locations of this data and the methods for generating the filenames are embedded in the data gathering scripts, described in Appendix B. Two types of data are used.

Solar Coronal Images

The sources of the images are two spacecraft instruments.

- EIT - The Extreme Ultraviolet Imaging Telescope on the SOHO spacecraft is a normal incidence narrowband instrument with 4 spectral channels isolating different temperatures. The FE XII 195 Å and FE XV 284 Å channels show the hottest material and are best for sigmoid detection. Emission in lines from lower temperature gas makes the images more confused than the normal incidence data.
- SXI - The Soft X-ray Imager on the NOAA GOES-12 spacecraft is a grazing incidence broadband instrument. It images higher temperature gas than EIT and shows sigmoidal structure more clearly, similar to the Yohkoh/SXT instrument that discovered coronal sigmoids. However, because it resides on an operational spacecraft rather than research spacecraft, it is in storage mode as of 20-Dec-2001 and is not expected to be in regular operation for about 1 year.

Tabular Text Data

The sources of this auxiliary data include space and ground instruments. Some are numerical, while others are summaries prepared by human operators.

Most of the tabular data are obtained from the Space Environment Center.

- AR numbers - Used to match sigmoid locations with NOAA regions.
- Flare events - Used to plot soft X-ray flares and Type II (shock driven) radio bursts.
- Geomagnetic - Used to display subsequent disturbances.

The LASCO group at NRL generates the list of Coronal Mass Ejections (CME). The list is updated about once per week and therefore is mostly retrospective.

The interplanetary data are obtained from the Advanced Composition Explorer spacecraft, located near the L1 Lagrangian point upstream from the Earth.

- Magnetic field.
- Solar energetic particles.