Prediction of Daily-Averaged MeV Electron Intensity at Geostationary Orbit

Version Description

UPOS-AUX-04

Version 2.0

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Table of Contents

1 Introduction

1.1 Project Overview

Satellites in space are instrumental in providing surveillance, communication, and navigation capability. Geomagnetic disturbances, which are related to enhancements of MeV electron intensity at geostationary orbit, can hamper these operations and can cause malfunction or failure of satellites and their onboard sensors. Accurate prediction of daily-averaged MeV electron intensity at geostationary orbit can be used to monitor the state of health of geostationary satellites in terms of daily dosage of these MeV electrons at the geostationary altitude. There is a recent significant advance in predicting the daily averaged intensity of energetic electrons at geostationary orbit based solely on real-time solar wind parameters and a simple radial diffusion model [Li et al., 2001]. In this model, a radial diffusion equation is set up to solve for the phase space density of energetic electrons in the radial range from $L = 4.5$ to $L = 11$, where L is McIlwain's L-shell parameter. The radial diffusion coefficient is controlled by the solar wind parameters. Additional effects from adiabatic response of electrons to magnetic field changes and solar wind dynamic pressure changes are incorporated through adjustments of the phase space density value obtained from solving the diffusion equation. This model provides a 1-2 days advance prediction of daily-averaged MeV electron intensity at the geostationary altitude.

In this project, we have followed basically the procedure introduced by Li et al. [2001] in the prediction of daily-averaged MeV electron intensity at geostationary orbit. The electron energy range tested for this project is 0.7-1.8 MeV. We have improved the model of Li et al. [2001] in a number of ways. First, we have extended the radial range in the diffusion equation solver. The L-shell range is from $L = 2$ to $L = 11$ for the present model. This extension holds the potential of predicting MeV electron intensity to other radial distances, such as those for GPS and LEO satellites. Second, we have extended the 1-2 days advance forecasting to 27 days advance forecasting. This extension assumes the persistence of solar surface features using the 27-day solar rotation period. Third, the dependence of diffusion coefficient on the phase of a solar cycle is partially corrected by the dependence of the normalization factor of MeV electron intensity on the phase of a solar cycle. Fourth, an additional term is added to the expression for the diffusion coefficient used by Li et al. [2001] to improve the prediction accuracy.

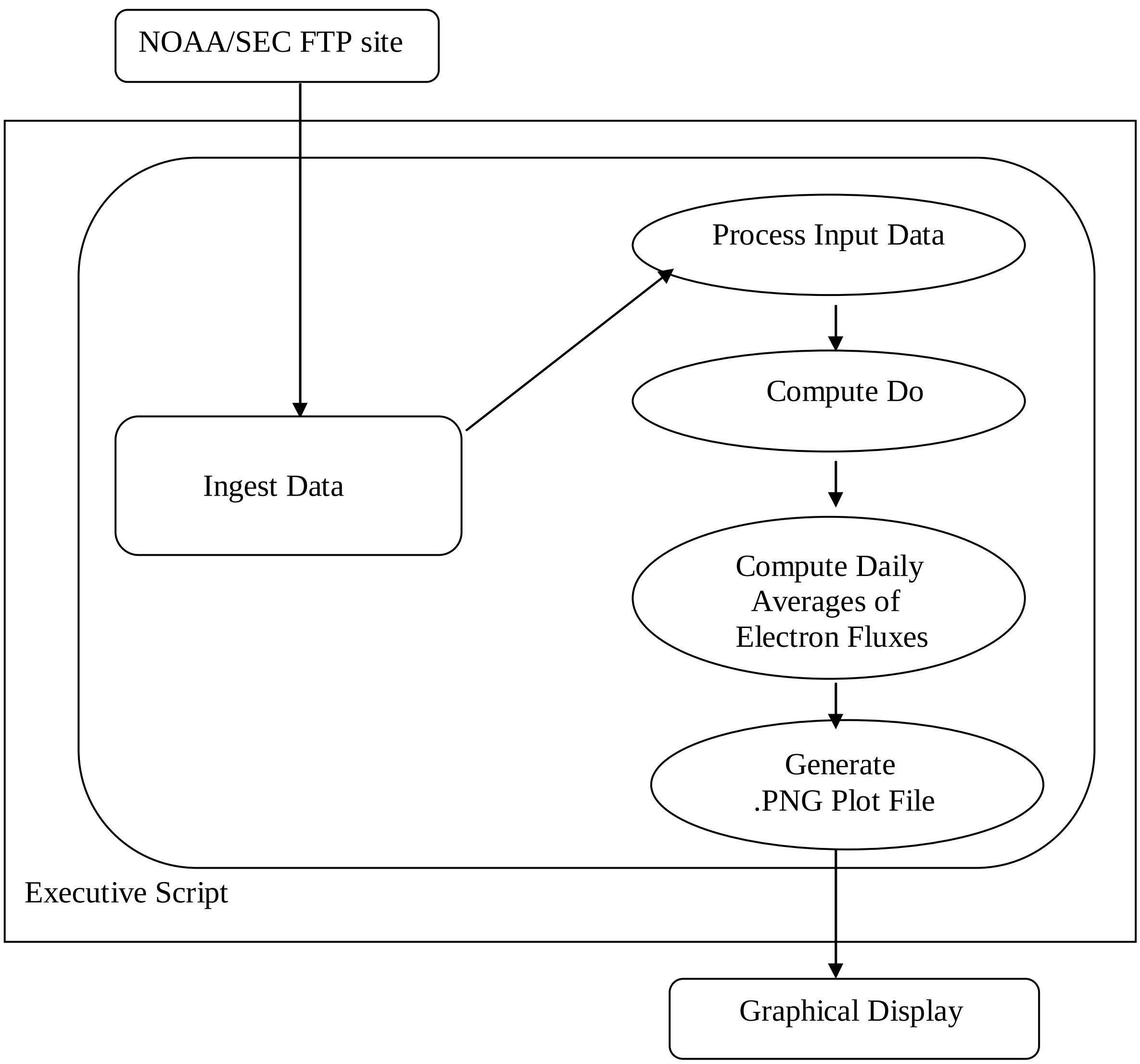
As an additional development of this project requested by AFWA, we have extended our prediction algorithm to energetic electrons >2 MeV. The coefficients used in solving the diffusion equation and linked to the solar wind parameters are optimized in matching with the observed daily-averaged >2 MeV electron flux through the nonlinear Levenberg-Marquardt method [Press et al., 2001] and a dynamic range correction formula.

References

Li, X., M. Temerin, D. N. Baker, G. D. Reeves, and D. Larson, Quantitative prediction of radiation belt electrons at geostationary orbit based on solar wind measurements, *Geophys. Res. Lett.*, *28*, 1887-1890, 2001.
Press, W. H., S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, Numerical Recipes in Fortran 77, p. 678ff, 2001.

1.2 System Overview

The software system used in this project to predict the daily-averaged MeV electron density at geo-synchronous orbit consists of Perl script, Unix shell script, IDL and FORTRAN programs. An executive script coordinates the execution of the software including data ingestion and processing, model runs and computations, and output generation. The graphic output can be viewed using most image viewers.



1.3 Document Purpose

Section 1 describes the scope of the project and software system. The software system is named as *MeV Electron Intensity Prediction Software System*.

2 Referenced Documents

Li, X., M. Temerin, D. N. Baker, G. D. Reeves, and D. Larson, Quantitative prediction of radiation belt electrons at geostationary orbit based on solar wind measurements, *Geophys. Res. Lett.*, *28*, 1887-1890, 2001.

3 Version Description

3.1 Inventory of Materials Released

This software system is being released on a single CD-Rom labeled MeV Software.

The documentation that supports this version of the *MeV Electron Intensity Prediction Software System* is listed below and has been delivered with installation of the system.

- UPOS-AUX-01 Design Document, Version 2.0, Tony Lui and Syau-Yun Hsieh, May 10, 2005
- UPOS-AUX-02 Functional Requirements, Version 2.0, Tony Lui and Syau-Yun Hsieh, May 10, 2005
- UPOS-AUX-03 Support Plan, Version 2.0, Tony Lui and Syau-Yun Hsieh, May 10, 2005
- UPOS-AUX-04 Version Description, Version 2.0, Tony Lui and Syau-Yun Hsieh, May 10, 2005
- UPOS-AUX-05 User's Guide, Version 2.0, Tony Lui and Syau-Yun Hsieh, May 10, 2005
- UPOS-AUX-06 Test Plan, Version 2.0, Tony Lui and Syau-Yun Hsieh, May 10, 2005

3.2 Inventory of Software Components

Appendix B contains the complete list of directories and files being delivered as Version 2.0 of *MeV Electron Intensity Prediction Software System*.

3.3 Change Installed

This is the first delivery of version 2 .0 of MeV software system.

3.4 Related Documents

All documents pertinent to Version 2.0 of the *MeV Electron Intensity Prediction Software System* are included in this release.

3.5 Software Installation Instructions

A UNIX system administrator will need to perform the installation and the acceptance testing for the UNIX version of the MeV Electron Intensity Prediction Software System.

3.5.1 Before installation

Before installing MeV software system, make sure that IDL, FORTRAN compiler, Perl, and WGET utility software are present on the UNIX workstation where the MeV software system is to be installed.

3.5.2 Installation Procedures

The installation procedures are the following steps:

<Step 1> un-tar *MeV_Software_ver_2_0.tar*

<Step2> In /src, you will find readme.pdf and three user-supplied files get_info1.dat, get_info2.dat, and get_info3.dat. Follow the instructions provided in readme.pdf to <u>edit</u> these three user-supplied files.

<Step 3>In /src, make a FORTRAN executable:

At Unix command line, type

% f77 –o sfd9_realtime compute_sfd9.f

<Step 4> In /src, at UNIX command line, type

% chmod 775 do_eflux27_ace_1n2
% chmod 775 go_eflux27_ace_1n2.pl

Then, modify the paths and file directory names in these two scripts if necessary.

<Step 5> Turn off "promping" when using command "rm" to remove files.

3.5.3 After installation

At this point, you are ready to run the software for near-real time prediction (See instruction in 3.5.3.2 of this section). You can perform a test to see whether you have done the installation correctly (See instruction in 3.5.3.1 of this section).

3.5.3.1 Running for Testing

To run this software in Test Mode, do the following steps:

<Step 1> In /src, follow readme.pdf to edit get_info1.dat, get_info2.dat and get_info3.dat for testing purpose.

<Step 2> In /src, at UNIX command line, type

% chmod 775 test_do_eflux27_ace_1n2
% chmod 775 test_go_eflux27_ace_1n2.pl

Then, modify the paths and file directory names specified in these two scripts if necessary.

<Step 3> To run the software, in /src, at UNIX command line, type

% test_go_eflux27_ace_1n2.pl

<Step 4> Compare result PNG files in /data with those provides in /sample_testresult

3.5.3.2 Running in Near-Real Time

To run software in near-real time mode, only do

<Step1> In /src, follow readme.pdf to edit get_info1.dat, get_info2.dat and get_info3.dat.

<Step 2> Set up a cron job to execute go_eflux27_ace_1n2.pl between time interval of 20:30 and 23:00.

Appendix A Inventory of Software Contents of Version 2.0

Directory /src			
Archive_files.pro	1KB	IDL code	
Cleanup_dir.pro	1KB	IDL code	
Compute_d0.pro	9KB	IDL code	
Compute_sfd9.f	6KB	FORTRAN Code	
Do_eflux27_ace_1n2	1KB	Shell script	
Find_doy.pro	1KB	IDL code	
Find_md.pro	1KB	IDL code	
Find_numdaysyear.pro	1KB	IDL code	
Generate_png.pro	4KB	IDL code	
Get_data.pro	6KB	IDL code	
Get_dirlist.pro	3KB	IDL code	
Get_info1.dat	1KB	ASCII data file	editable
Get_info2.dat	1KB	ASCII data file	editable
Get_info3.dat	1KB	ASCII data file	editable
Get_predictions.pro	17KB	IDL code	
Go_eflux27_ace_1n2.pl	1KB	Perl script	
Nu_initpsd	3KB	ASCII data file	
Output_plot.pro	1KB	IDL code	
Plot_ps.pro	1KB	IDL code	
Process_ace_data.pro	29KB	IDL code	
Process_eflux_p27.pro	6KB	IDL code	
Process_goes_data.pro	8KB	IDL code	
Process_goes_p27.pro	4KB	IDL code	
Process_sw_p27.pro	11KB	IDL code	
Run_eflux27_ace_1n2.pro	1KB	IDL code	
Run_eflux_ace_1.pro	4KB	IDL code	
Run_eflux_ace_2.pro	3KB	IDL code	
Test_do_eflux27_ace_1n2	1KB	Shell script	
Test_get_data.pro	5KB	IDL code	
Test_go_eflux27_ace_1n2.pl	1KB	Perl script	
Test_run_eflux27_ace_1n2.pro	1KB	IDL code	
Test_run_eflux_ace_1.pro	4KB	IDL code	
Test_run_eflux_ace_2.pro	3KB	IDL code	
Xticks.pro	1KB	IDL code	
Readme.pdf		Text file	
Total of 34 files			

Directory /data			
A00000.dat	0KB	Empty data file	
Total of 1 file			

Appendix B Acronyms and Abbreviations

Acronym	Definition
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
CME	Coronal Mass Ejections
COE	Common Operating Environment
Dst	Disturbance, storm
DII	Defense Information Infrastructure
DMSP	Defense Meteorological Satellite Program
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
HLBL	High Latitude Boundary Layer
IDL	Interactive Data Language
IMF	Interplanetary Magnetic Field
ISS	International Space Station
JHU	Johns Hopkins University
LAN	Local Area Network
LAPS	Local Analysis and Prediction System
LEO	Low-attitude Earth Orbit
LSM	Land Surface Model
MeV	Million Electron Volts

MM5	Fifth Generation Mesoscale Model
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction System
NWP	Numerical Weather Prediction
OWS	Operational Weather Squadron
PACE	Poloar Anglo-American Conjugate Experiment
PBL	Planetary Boundary Layer
PCA	Polar Cap Absorption
PFRR	Poker Flat Research Range
SD	Space Department of the Applied Physics Laboratory
SDP	Software Development Plan
SEC	Space Environment Center
SEE	Solar EUV Experiment
SEON	Solar Electro-optical Observing Network
SEP	Solar Energetic Particles
SFOC	Spaceflight Operations Center
SPE	Solar Particle Event
UAF	University of Alaska, Fairbanks
UCAR	University Corporation for Atmospheric Research
UPOS	University Partnering for Operational Support
UTC	Coordinated Universal Time