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Solar Irradiance Modelling

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Abstract: ***CTSI is the solar energy received on outer layer of earth (at 1AU distance from sun) in form of heat flux (in various wavelength bands) measured in w/m^2. SSA is the area of visible sunspot on photosphere of sun. B is the daily averaged solar global magnetic field. The CTSI & SSA shows delay[9] with respect to each other. 27day running averaged values of CTSI, SSA, and B for delayed events are suitably combined in solar irradiance modelling .Using solar data for cycles 21, 22, 23 about 6 modelling equations are developed for solar irradiance. The modelled equations very well predict solar irradiance (RAWCTSI) within an error limit of +/- 0.12 w/m^2.***

Keywords: Sun, CTSI, SSA, Average solar magnetic field (B), Delay

1. Introduction

CTSI (composite total solar irradiance) is the solar energy received on outer layer of earth (at 1AU distance from Sun.) in form of heat flux measured in W/M^2 (in various wavelength bands). **SSA** is the area of visible sunspot, as seen on photosphere of sun which is nothing but visible area of broader end of sunspot vortex[9].**B** is the daily averaged solar global magnetic field as discussed in earlier paper[9].**CTSI** & **SSA** shows delay[9] with respect to each other.

27day running averaged values of CTSI, SSA, B (ie.27CTSI, 27SSA, 27B) for delayed events in suitable combinations leads to solar irradiance modelling.

Using solar data for cycles 21, 22, 23 about 6 modelling equations are developed for composite total solar irradiance (CTSI). The best model predicts solar irradiance within a minimum error limit .The modelled equations very well predict the practical RAWCTSI (ie. satellite data), coinciding in phase with raw data with an amplitude difference of 0.12 w/m^2.

The study of parameters involved in modelling equations gives an insight about their intrinsic nature and their intrinsic contribution to solar output energy.

2. Theory

As discussed in the earlier paper[9] sunspots are approximated as vortices in developing or decaying stages. New born vortices(baby vortices) are called as SLVs .Usually SLVs are found at the higher latitudes popularly called as **pores** .They grow while they migrate towards lower solar latitudes .Matured vortices are called MLVs popularly called as **sunspots.** At solar minima **SLVs** dominate & **MLVs** dominate at solar maxima.

During growth SLVs enter magnetically quantised latitudinal belts. The magnitude of magnetic field of quantised belt is decided by size of vortex. Thus change of dimension of vortex shifts it to the neighbouring latitudinal belt. While shifting the longitudinal wise meridonal circulation takes away/puts the vortices in appropriate magnetic belts. Thus a meridonal flow directed to words the equator carries growing vortices while that to words the pole carries decaying vortices. The solar energy received as solar radiation at 1 AU distance (i.e. on earth's surface) varies as a function of average global magnetic field (B) of sun. This is a clear indication of the fact that solar radiations are electromagnetic waves liberated by sun and received on earth.
Thus variation in B can be studied by studying variations in solar radiations or vice versa, in various wavelength bands. Thus B plays a very important role in solar irradiance modelling.

The analytical equations developed for solar irradiance modelling are depicted in figs 27, 28, 29,30,31,32

3. Method

The solar data is analysed using idlde 5.4 packages on UNIX platform using sun Microsoft computer. The data for CTSI, SSA, and B are downloaded from URLs cited in the data reference section for solar cycle 21, 22, 23. The data is subjected to 27 day running averaging after removing all data gaps. Simultaneous plotting and analysis leas to identification of delayed events[9].The values of 27CTSI, 27SSA, 27B for delayed events are determined from the graph and tabulated. These data are used for further analysis. Various combinations of modelling parameters tried are depicted in fig 27,28,29,30,31,32 as MODELI,II,III,IV,V,VI

4. Results

Table1: Modelling Parameters

S. No	Model	Modelling Parameters	% error ; error limit; trend	Corr. Coeff	Remarks
1	Model I	delay&27CTSI delay &27SSA delay &27B	2.5 to 4.5 % ; 2 % ; +ve	-0.0065351088 -0.032088904 -0.0193102	3 stage modelling
2	Model II	27CTSI&27SSA 27SSA & 27 B 27B & DELAY	-0.08 to 0.12 % ; 2 % ; towards +ve	0.42429303 -0.0048808803 -0.0193102	3 stage modelling
3	Model	RAWCTSI &27B	-0.08 to	0.046485802	3 stage

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	III	27B &DELAY DELAY&RAWSSA	0.12 % ; 2 % ; towards +ve	-0.0193102 -0.032088804	modelling
4	Model IV	RAWCTSI &27SSA 27SSA & 27B 27B & DELAY	-0.12 to 0.08 % ; 2 %; towards -ve	0.28271201 - 0.0049808903 -0.0193102	3 stage modelling
5	Model V	RAWCTSI & 27CTSI 27CTSI & 27SSA RAWSSA & 27B 27B &DELAY	-0.12 to 0.08 % ; 2 % ; towards -ve	0.70871887 0.42428303 - 0.0049606903 -0.0193102	4 stage modelling
6	Model VI	RAWCTSI & RAWSSA RAWSSA & 27SSA 27SSA & 27B 27B & DELAY	-0.12 to 0.08 % ; 2 %; towards -ve	0.0404318 0.74821774 - 0.0049505903 -0.0193102	4 stage modelling

The characteristics of different models are as below.

MODEL I: parameters involved are delay, 27SSA, 27CTSI, 27B. The sequences of correlation /action/path chosen are Delay & 27CTSI, Delay & 27SSA, delay &27B (i.e. 3 stage modelling). This is an initial effort which clearly shows that even though the modelled CTSI follows the trend of RAWCTSI, an error of 2.5 to 4.5 % is produced in the modelled CTSI. Such high degree of error may be due to choosing improper sequence of correlation/path.

MODEL II:
The parameters involved are delay, 27CTSI, 27SSA, 27B. The sequences of correlation/action chosen are 27CTSI &27SSA, 27SSA & 27 B, 27B & DELAY (ie.3 stage modelling).

27CTSI is strongly positively correlated to 27SSA (corr. coefficient, cc=0.42429303).

27SSA is weakly anti correlated to 27B (cc=-0.0049808903) probably this is an indicator of the fact that if the number of cases studied increases the correlation may turn out to be positive.

27B is anti correlated to delay (cc=-0.0193102) again a feable negative correlation, which may turn out to be positive if number of cases studied increases

MODEL III:

The parameters involved are, RAWCTSI &27B (0.046455602), 27B & DELAY (CC=-0.0193102), DELAY &RAWSSA (CC=-0.032055904)**, i.e**. 3 stage modelling overall a feable positive correlation.

MODEL IV:

The parameters involved are RAWCTSI VS 27SSA (0.29271201),
27SSA VS 27B (-0.0049505903), 27B VS DELAY (-0.0193102), i.e. 3 stage modelling
Overall a feable positive correlation.

MODEL V

The parameters involved are RAWCTSI VS 27CTSI (CC=0.70571567),
27CTSI VS 27SSA (CC=0.42429303), RAWSSA VS 27B (CC=-0.0045605903),
27B VS DELAY (-0.0193102), i.e. 4 stage modelling
Over all positive strong correlation trend set in.

MODEL VI: The parameters involved are RAWCTSI VS RAWSSA? (CC=0.0404318),
RAWSSA VS 27B (CC=0.74521774), 27SSA VS 27B (CC=-0.004505903),
27B VS DELAY (CC=-0.0193102), i.e. 4 stage modelling
Confirming the set in of overall positive correlation.

All the models show about 2% errors, but what differentiate one from another are the error limit and its trend. The trend shifts from positive in model I,II,III to negative in model IV,V,VI (ie. error limit stretch is overall positive in model I, while tends to positive in model II,III and tends to negative in model IV,V,VI).

A good model should have equal error stretch in positive & negative regions (symmetric stretch).In this way models IV, V, VI are improved version over II, III.

Correlation factors play an important role during modelling because constructive way of modelling requires parameters showing similar type of correlation i.e. positive cc or negative cc. If this idea is taken in to account MODEL V is the best because all cc‘s involved shows almost positive trend. Next best is;

MODEL VI .Correct sequence of action is RAWCTSI & 27CTSI, 27CTSI & 27SSA, RAWSSA & 27B, 27B & DELAY.

5. Conclusion

MODEL V is the best model, but still requires correction for 3rd and 4th sequence of action.

6. Direction for Future Study

a) MODEL V can be improved by correcting 3rd & 4th sequence of action.
b) The modelling can be studied by choosing recurring events at a fixed interval of time for example 27days, 54days, 181days, 366 days etc. Each recurrence has got its own significance in contributing towards solar irradiance, ie. The solar energy received on surface of earth.

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Data Reference:

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[11] SSA database

11a) 1978 to 1982

ftp://fenyi.solarobs.unideb.hu/DPD/data/1)16/11/1978 to 31/12/1982 Greenwich daily data
URLS used are
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1978.sum
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1979.sum
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1980.sum
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1981.sum
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1982.SUM
11b) 01/01/1983 TO 31/12.1985 data not available
2c) 1986-2002 DPD DAILY DATA URL used is ftp://fenyi.solarobs.unideb.hu/DPD/data/

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Author Profile

Smt Rohini V.S. is working as Associate Professor in Govt First Grade College, Sira, Tumkur district. Participated in many national & international conferences and presented papers. She published many papers is national and international journals. She is actively engaged in solar astrophysics. Her subject of interest is magneto convection, sunspot, quantised magnetic belts, irradiance modelling etc. She is recipient of many prizes, honours, certificates of appreciation. Students are working under her guidance for MPhil & PhD degrees.

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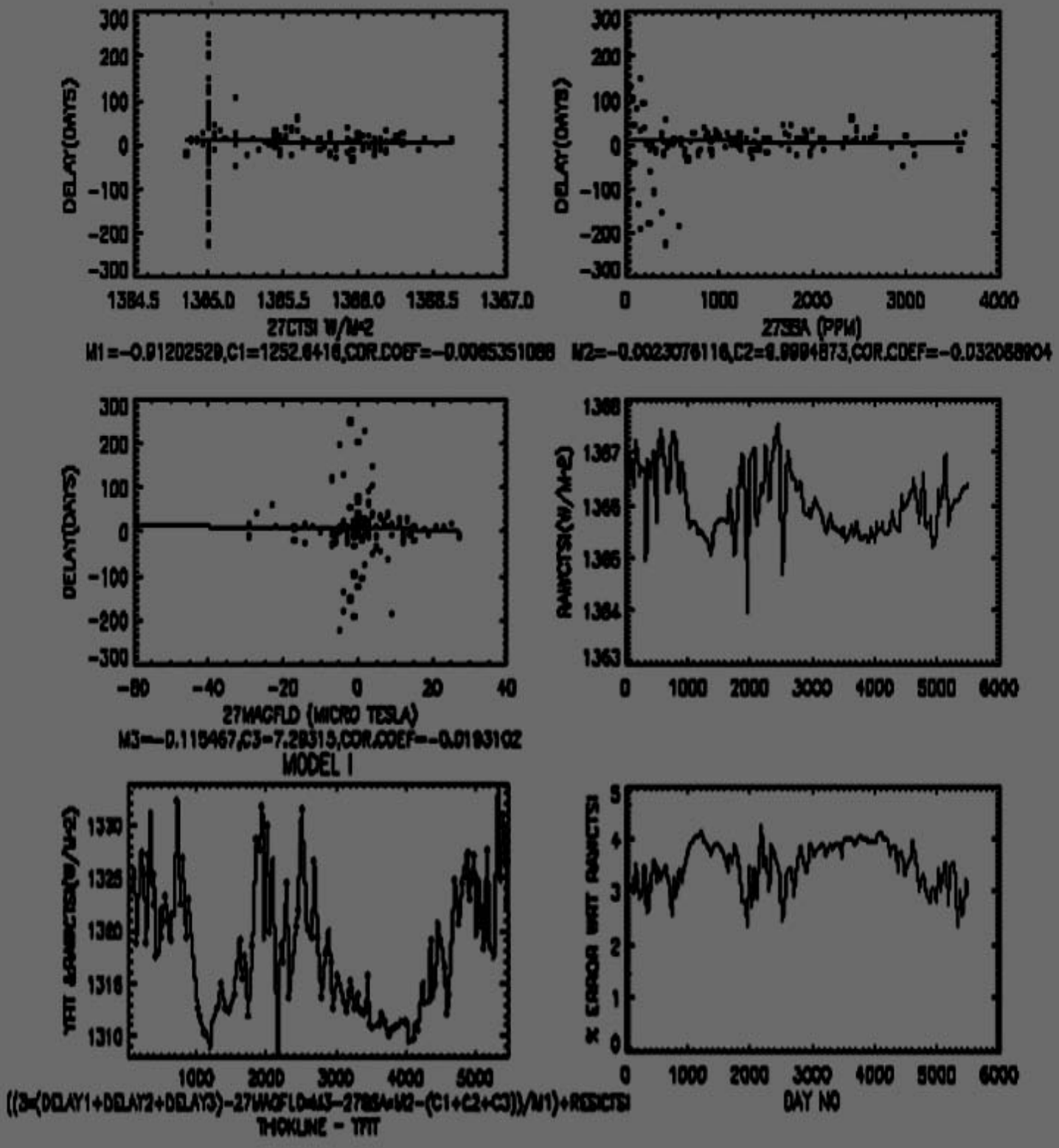


FIG27:SOLAR CYCLE21,22,23 MODELLING MODEL I

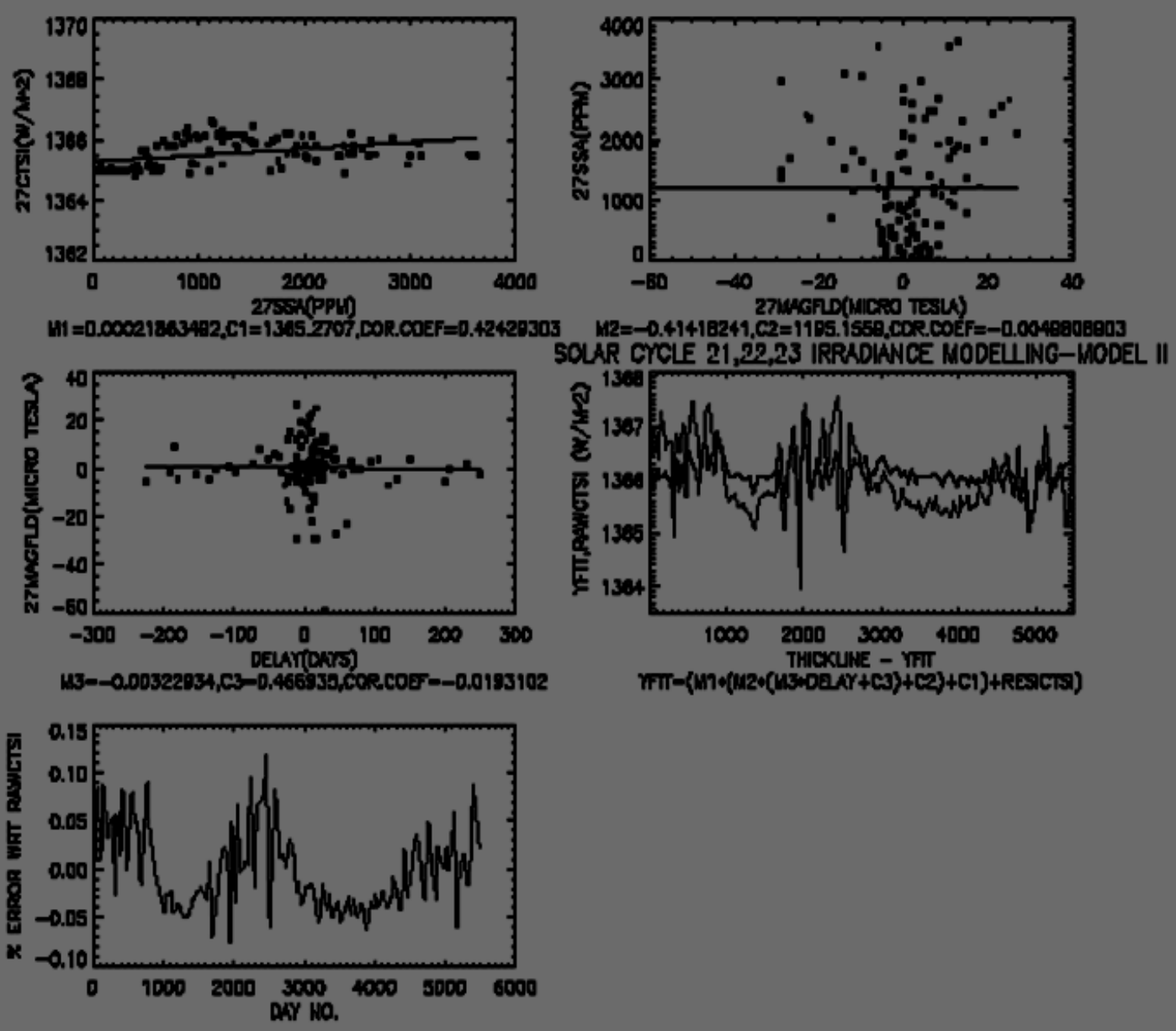


FIG 28:SOLAR CYCLE 21,22,23-IRRADIANCE MODELLING MODEL II

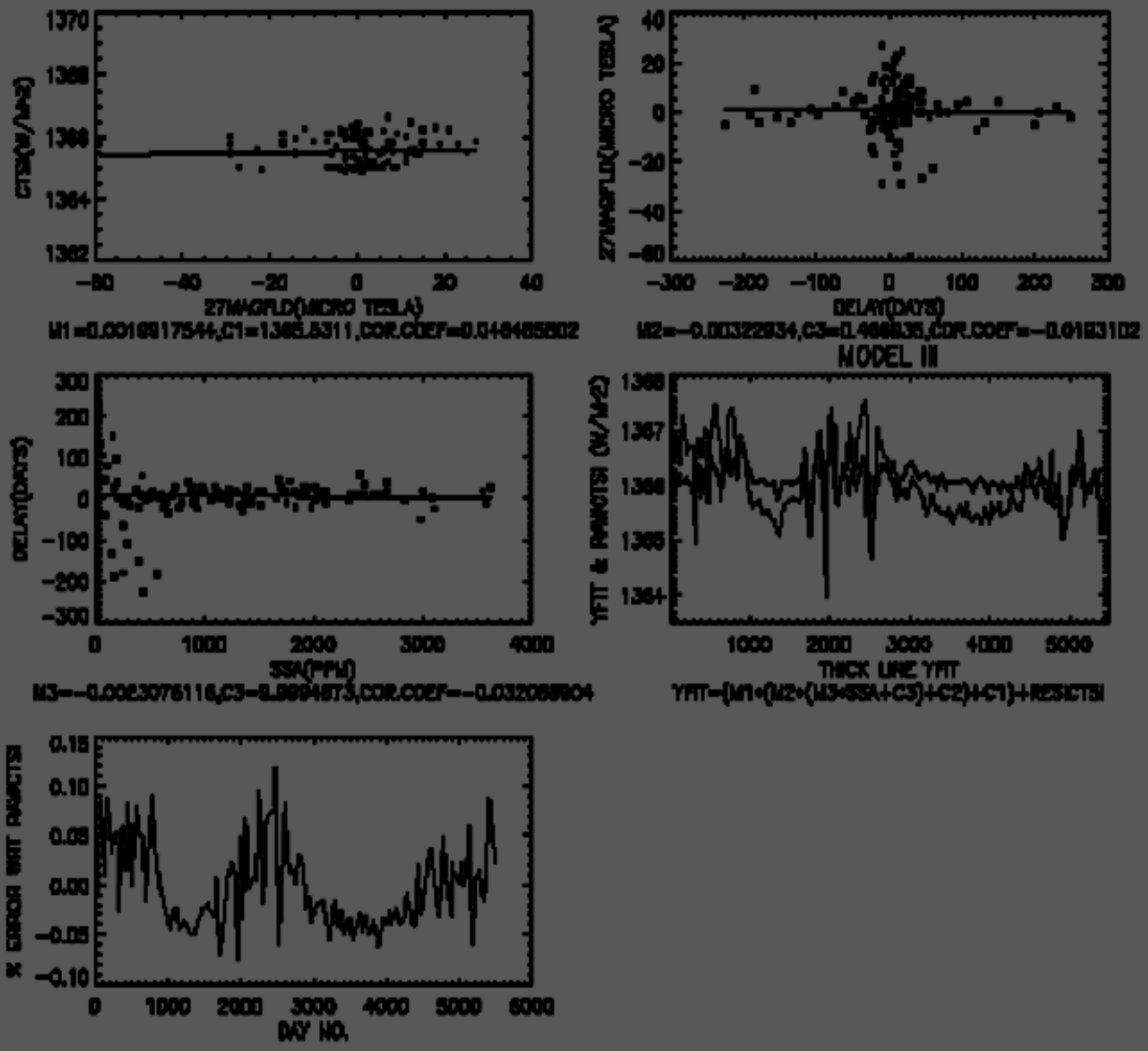


FIG29: SOLAR CYCLE 21,22,23- IRRADIANCE MODELLING MODEL III

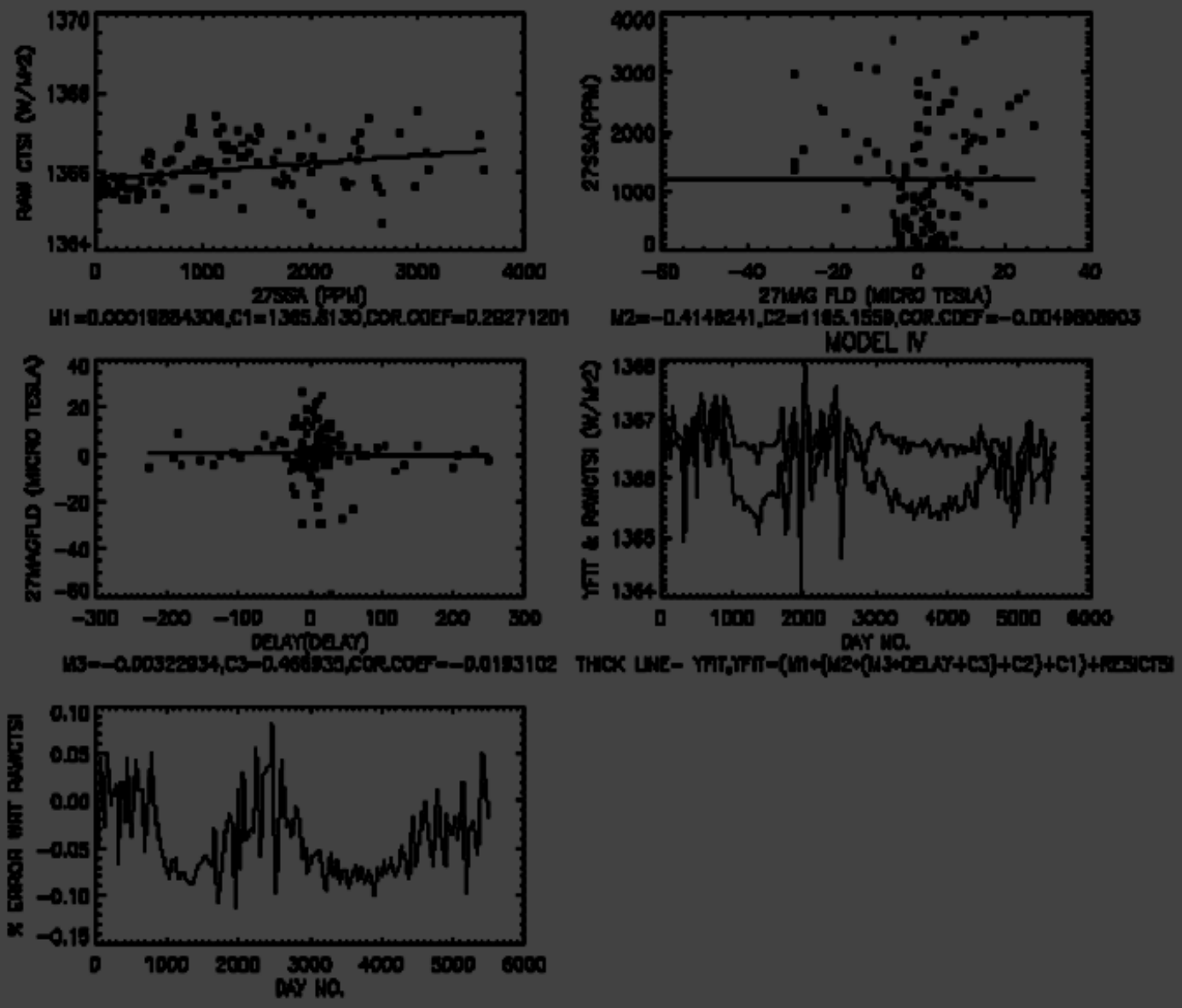


FIG 30: SOLAR CYCLE 21,22,23-IRRADIANCE MODELLING MODEL IV

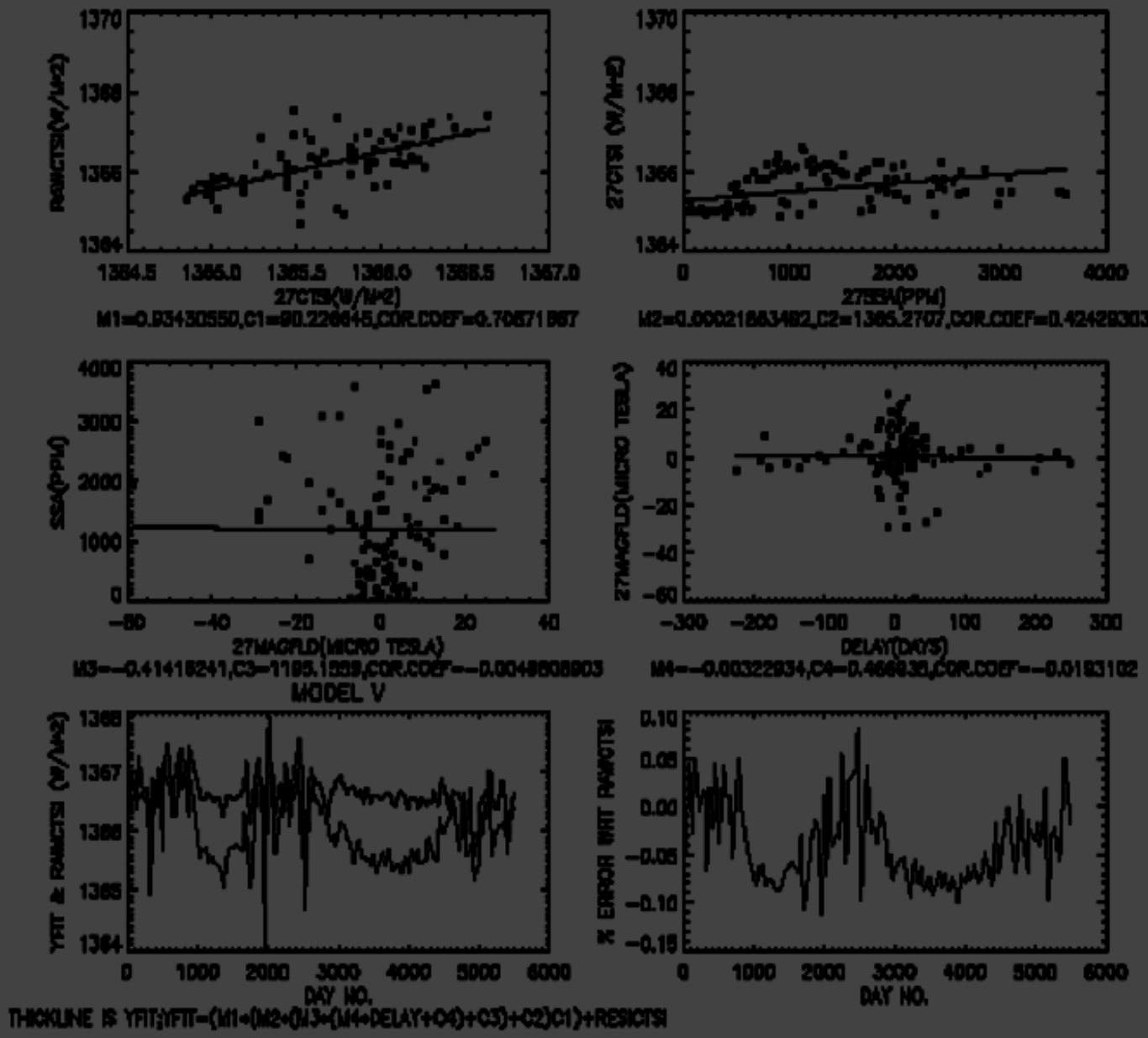


FIG 31: SOLAR CYCLE 21,22,23-IRRADIANCE MODELLING MODEL V

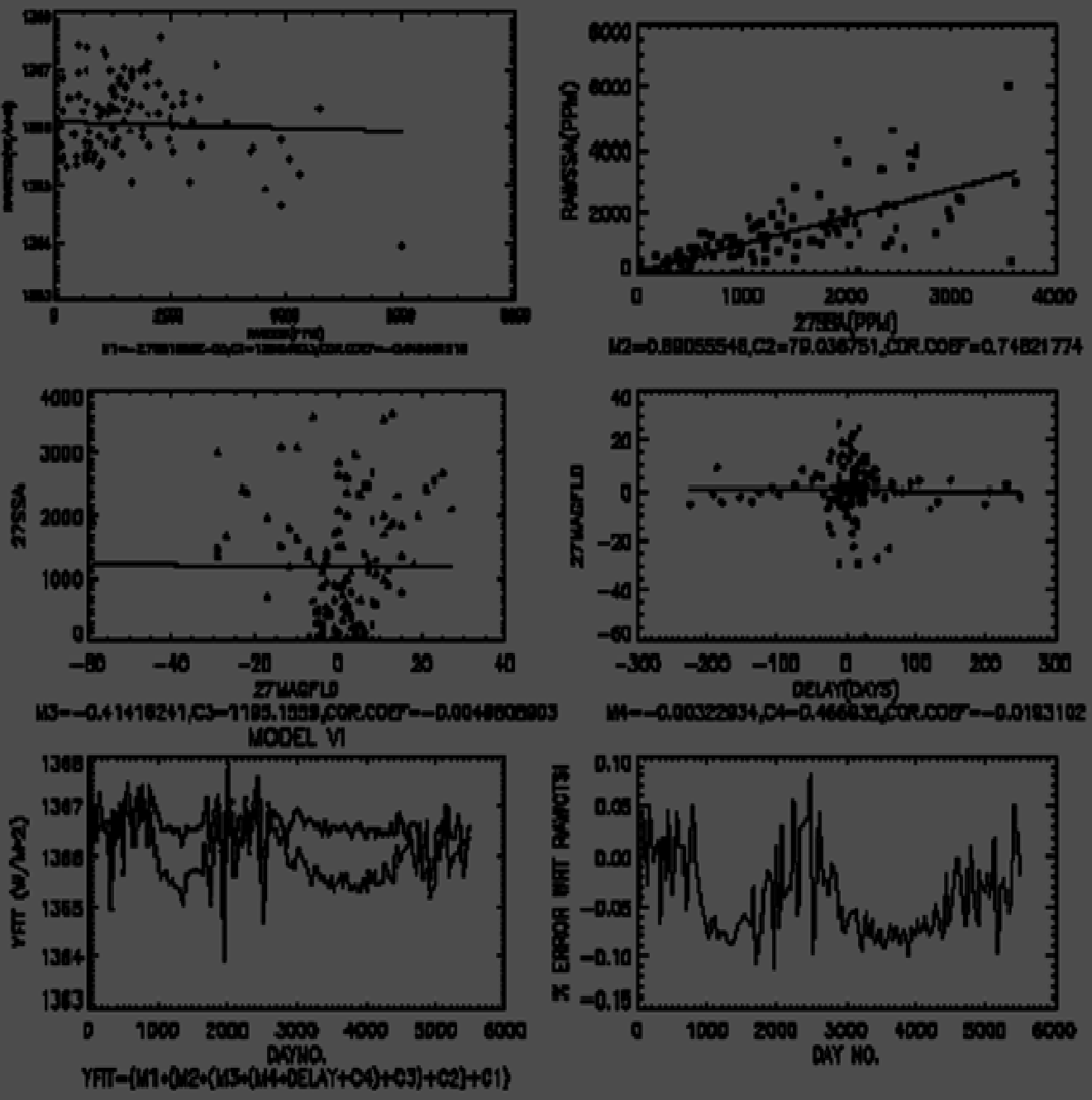


FIG 32: SOLAR CYCLE 21,22,23-IRRADIANCE MODELLING MODEL VI