Empirical model for predicting the occurrence of major geomagnetic storms during SC23

M. Mierla[1,2,3], C. Oprea[2], N. Srivastava[4], L. Rodriguez[1], D.Besliu-Ionescu[2], O. Stere[2], G. Maris Muntean[2]

1. STCE - Royal Observatory of Belgium, Brussels, Belgium
2. Institute of Geodynamics of the Romanian Academy, Bucharest, Romania
3. Research Center for Atomic Physics and Astrophysics, University of Bucharest, Romania
4. Udaipur Solar Observatory, Physical Research Laboratory, Udaipur, India

Contents

Aim of the Study

Definition

CMEs are ejections of parts of the magnetized solar atmosphere that occur over the course of hours to days.

Do they influence us? - Yes

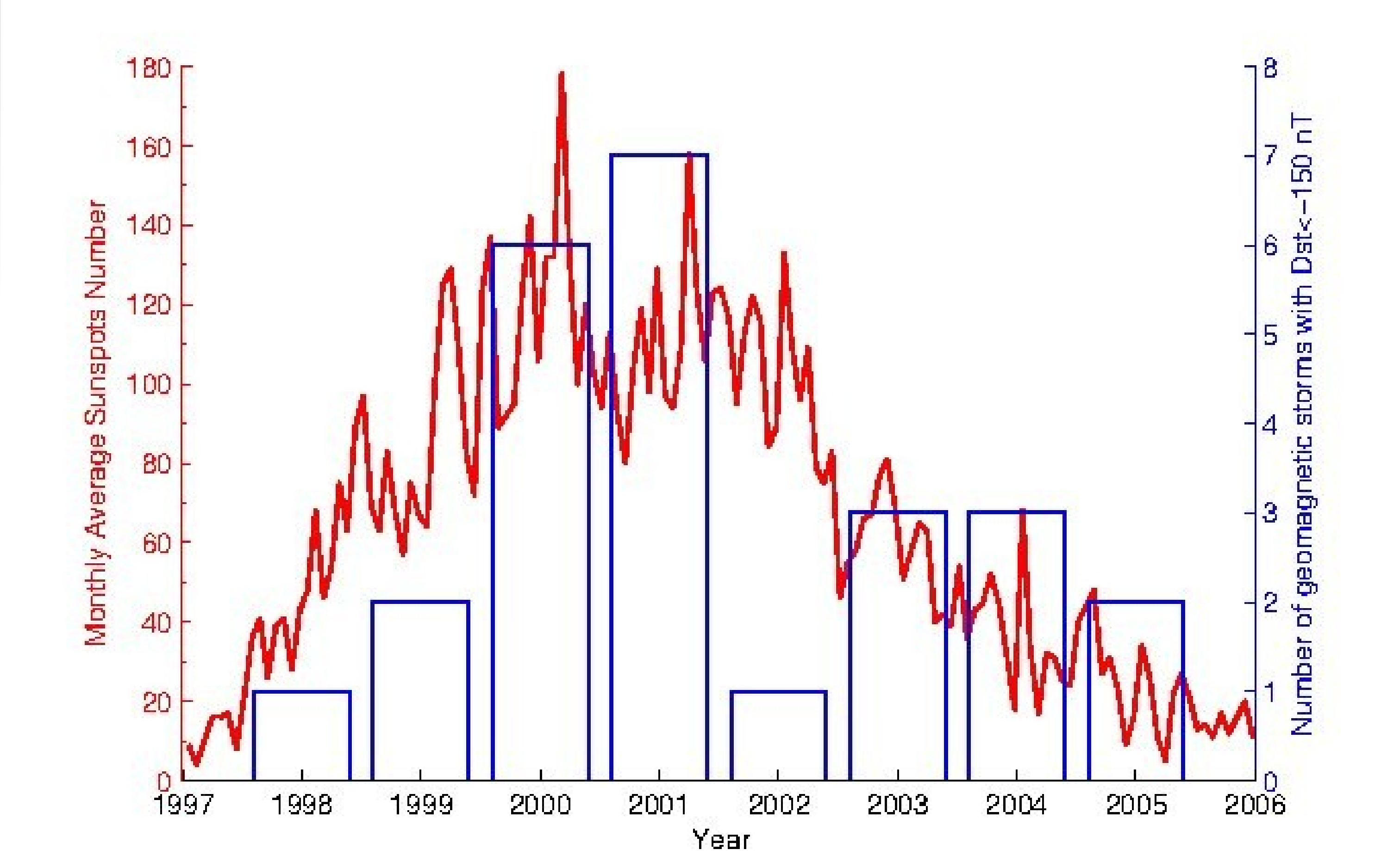
When directed towards the Earth they can create major disturbances in the magnetosphere.

During SC23 there were 25 major geomagnetic storms (Dst < -150 nT) for which clear CMEs could be associated.

Applying a logistic regression model on these events we try to forecast the occurrence of major storms.

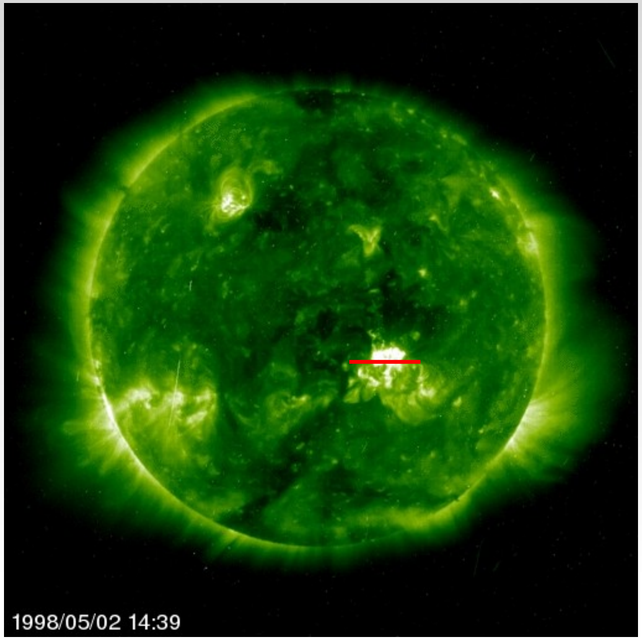
Data

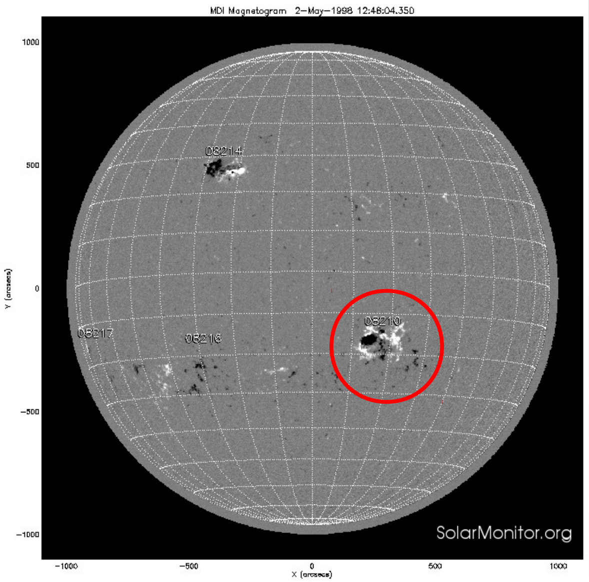
- 25 CMEs during SC 23 which have produced major geomagnetic storm (Dst < -150 nT)

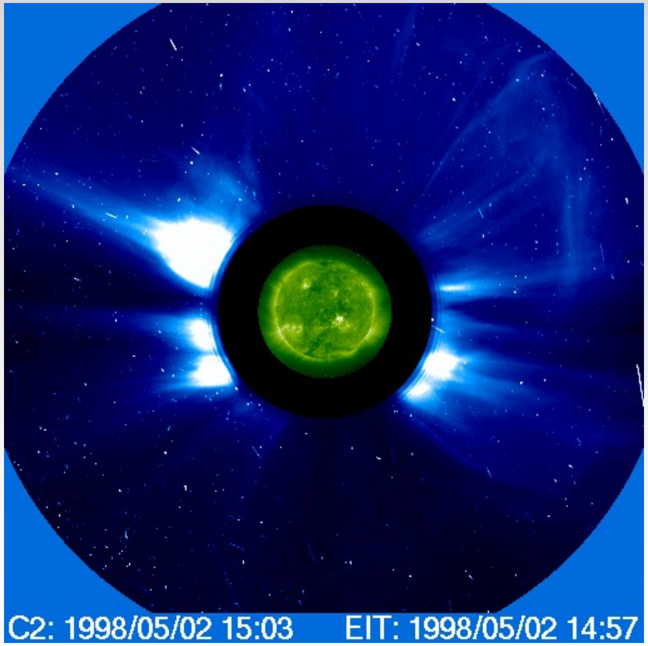


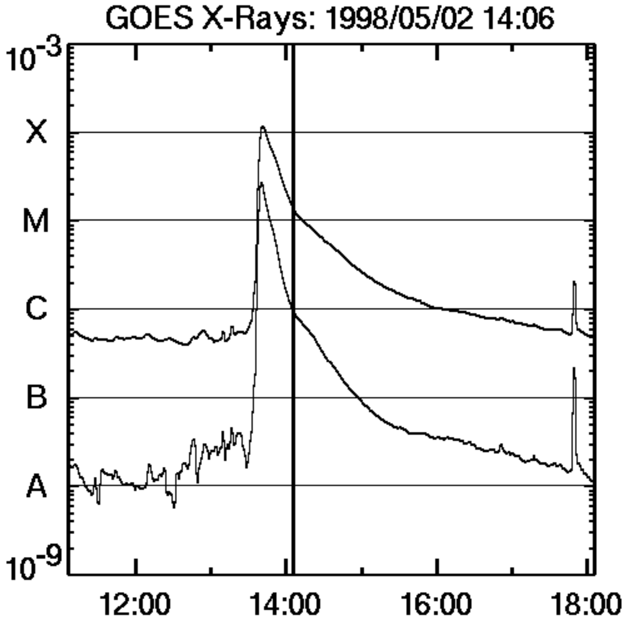
Oprea et al., submitted to AnnGeoph.

CME on 2-May-1998









Flare: X1.1

- Start: 13:31 UT
- End: 13:51 UT
- Maximum: 13:42 UT

Source location: AR 8210

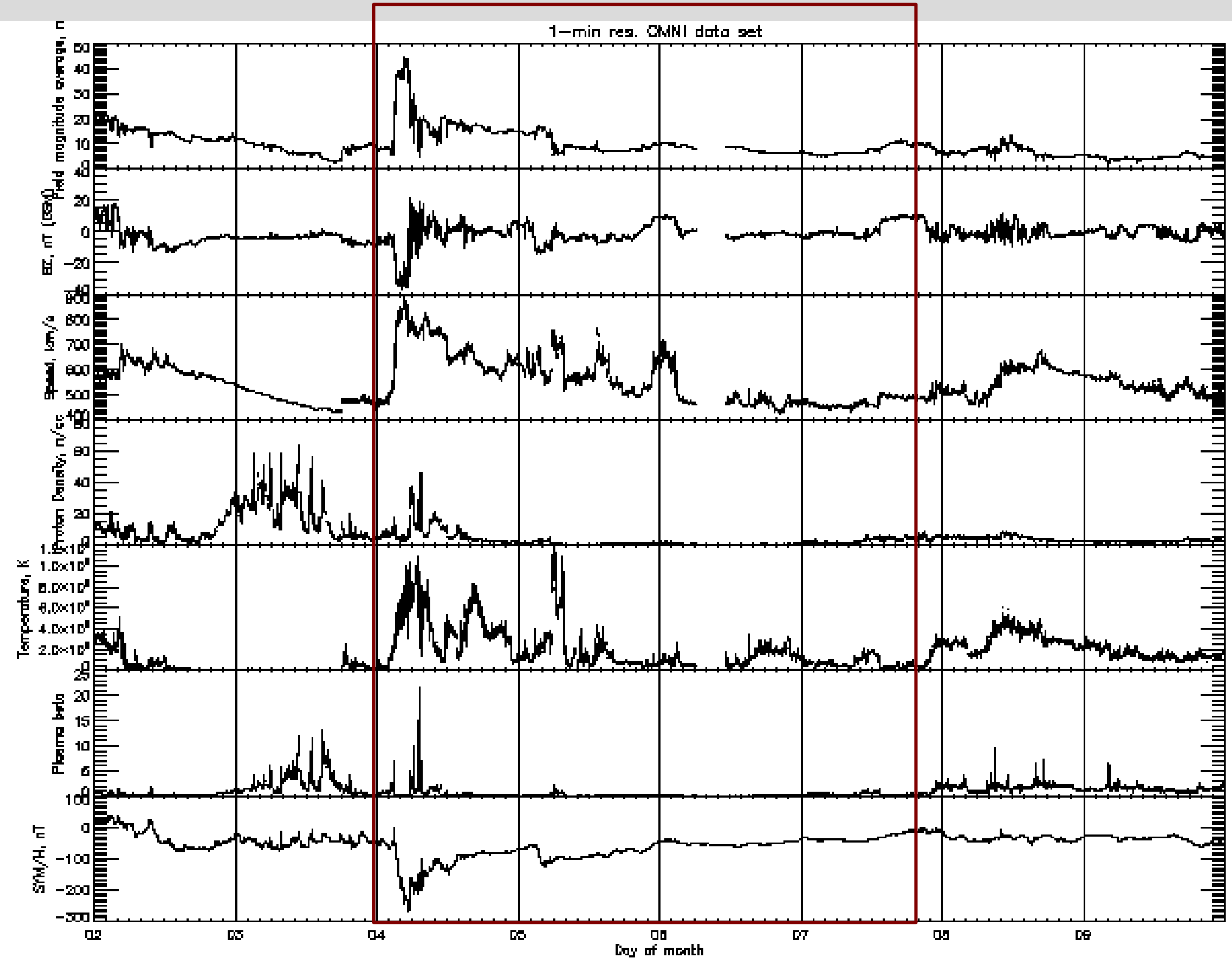
- S15W15
- AR type: γδ

Speeds (km/s):

- Vproj = 697
- Vrad = 1543
- Vtt = 700

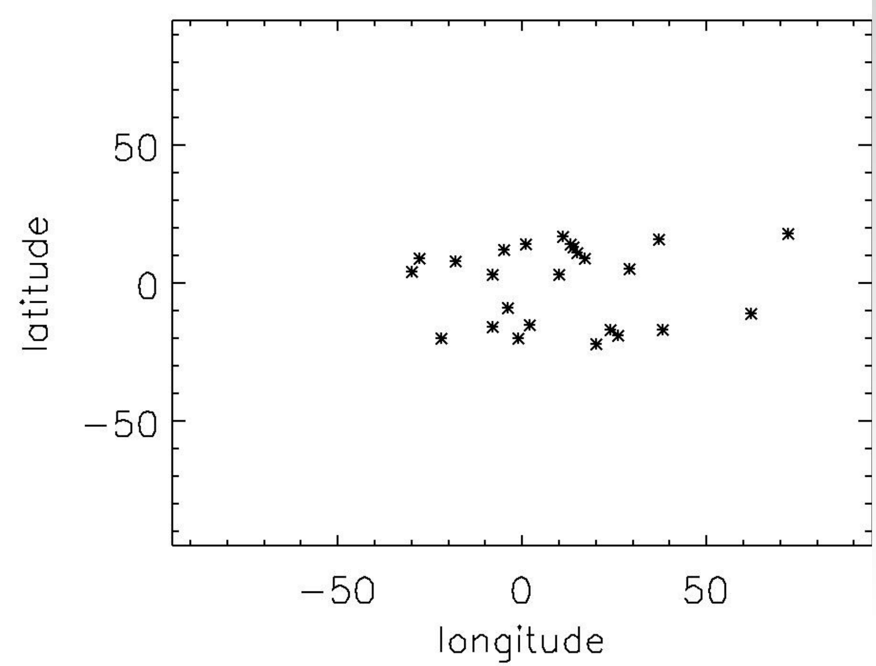
The CME was first seen by LASCO-C2 at around 14:06 UT

ICME on 4-May-1998

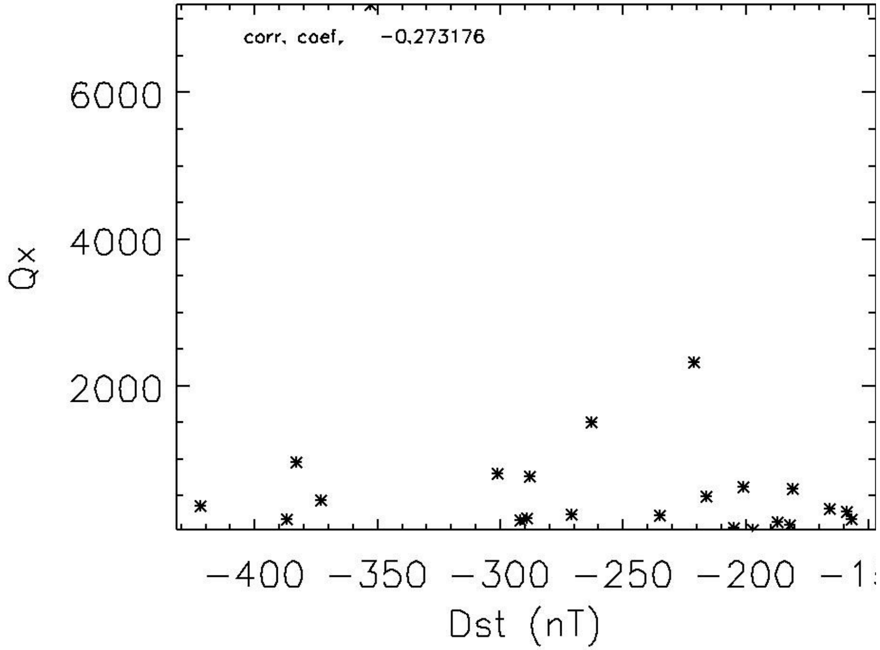


Interval: 02 - 09 May 1998

Analysis – Source location and flare importance

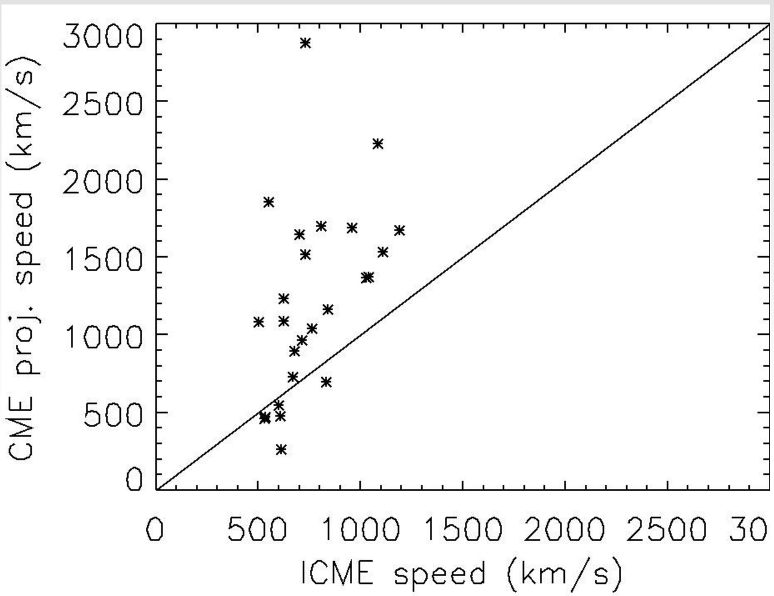


Flare importance versus Dst index

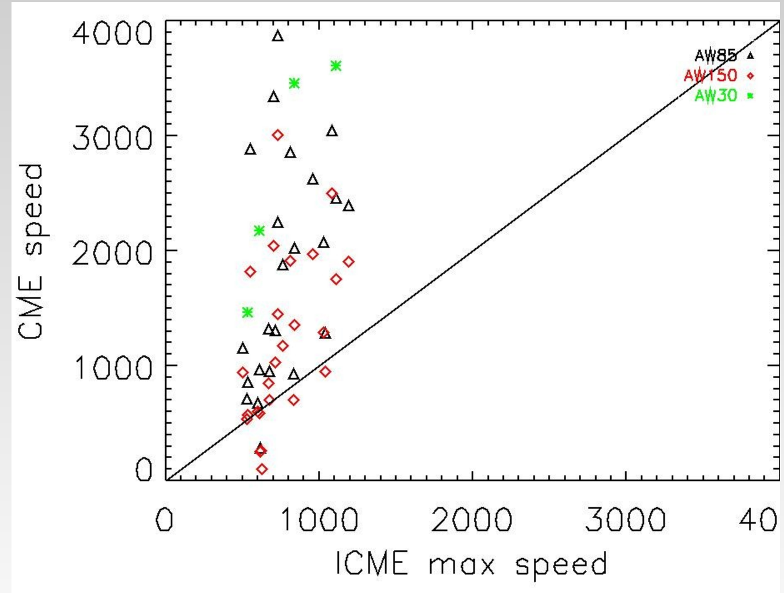


Latitude vs longitude for CMEs sources

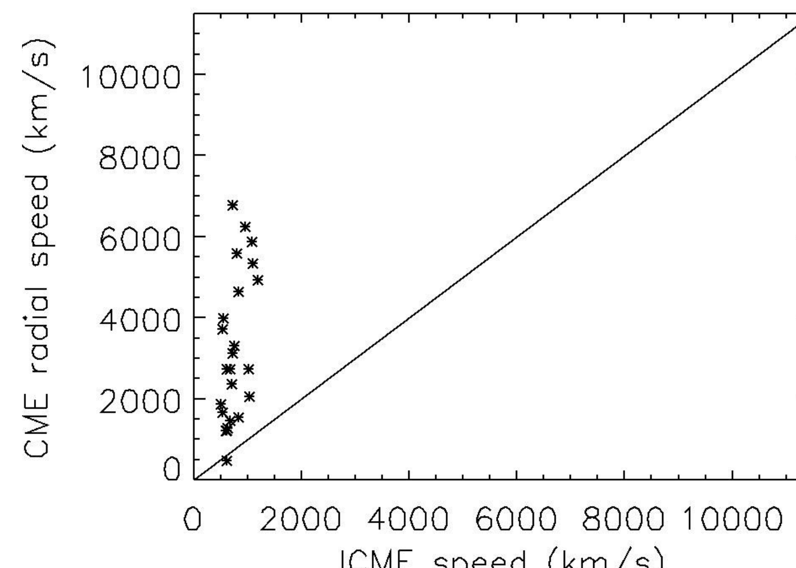
Analysis – Speeds



CME projected speed measured in LASCO versus ICME maximum speed measured at ACE

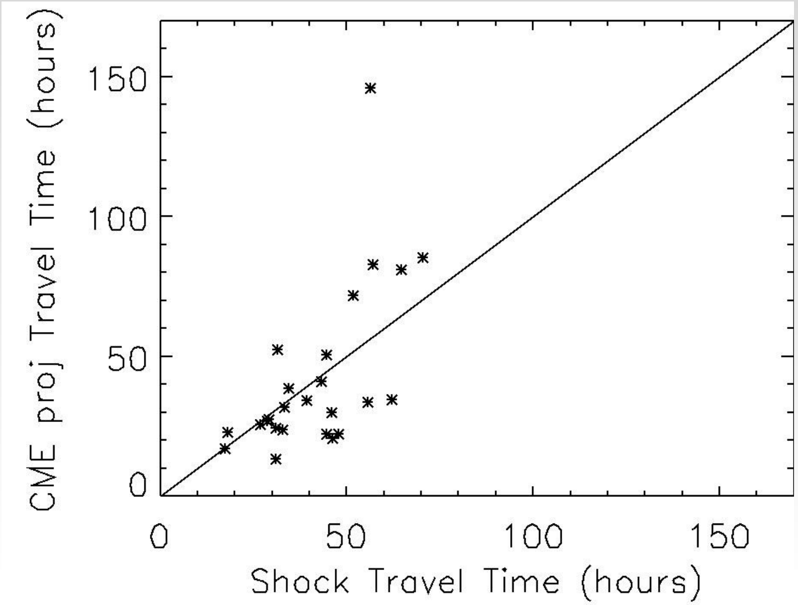


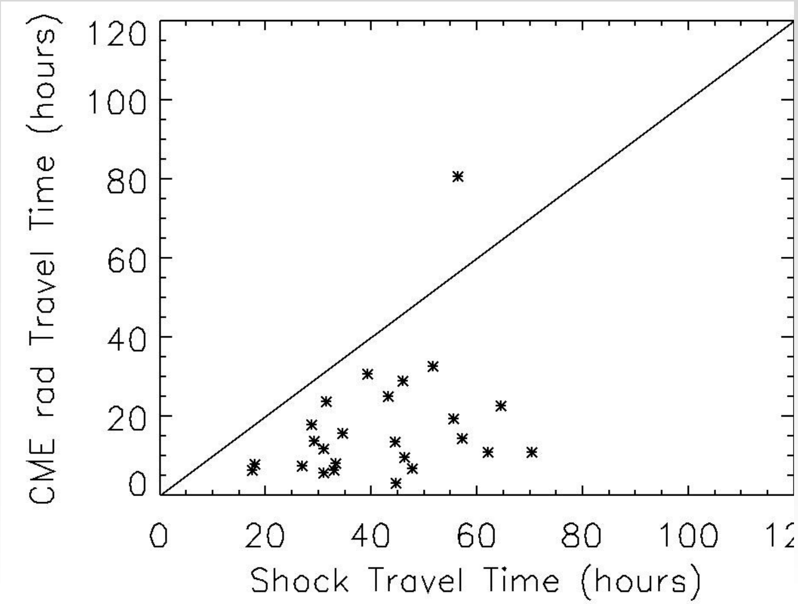
CME speed measured using the model of a radially, self-expanding sphere versus the ICME maximum speed.

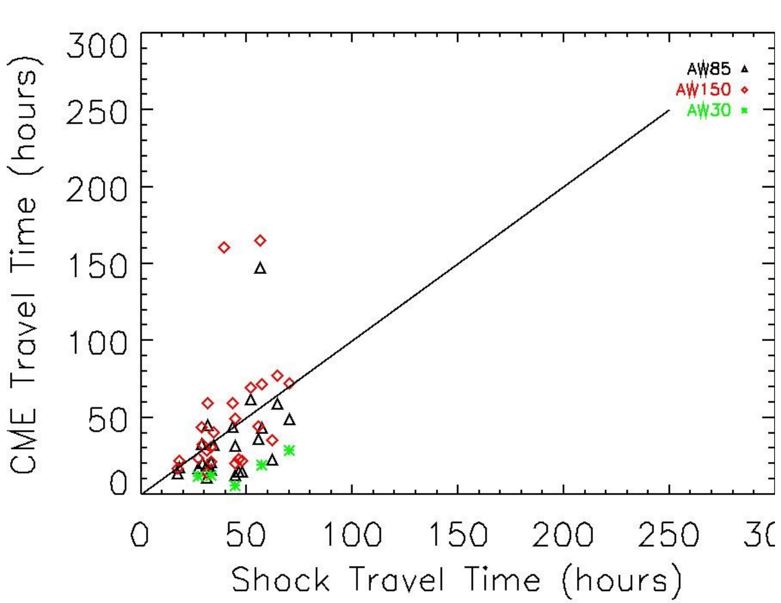


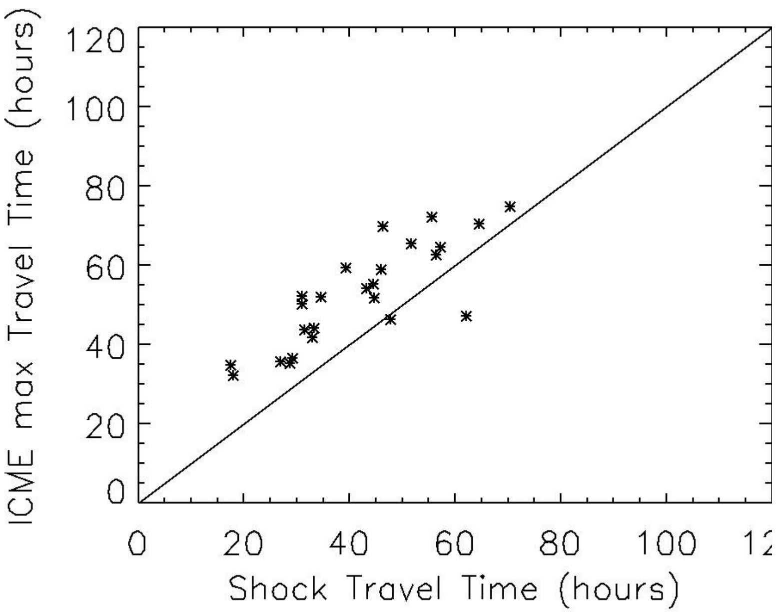
CME de-projected speed versus ICME maximum speed.

Analysis – Travel time









The model (1)

Statistical model for predicting the geomagnetic storms (Srivastava 2005):

$$GMS = [f\,(SP_i),\ P_k]$$

- GMS = the occurrence of a geomagnetic storm,
- SP_i (i=I) is the ith solar variable,
- P_k (k=K) is the kth parameter of the function f that relates the solar variables to the occurrence of a geomagnetic storm,
- I and K are the total numbers of solar variables and function parameters.

Logistic regression model: for modeling the relation in the above equation, in order to predict the occurrence of a major geomagnetic storm.

Estimate **the probability** of the occurrence of a major geomagnetic storm given the incidences of the solar variables.

The model (2)

Estimate **the probability** of the occurrence of a major geomagnetic storm given the incidences of the solar variables.

$$\Pi_i = 1/(1+e^{-Z_i})$$

$$Z_i = b_0 + b_1 x_{i1} + b_2 x_{i2} + b_3 x_{i3} + \ldots + b_j x_{ij}$$

$\boldsymbol{\Pi_i}$ = the probability of the occurrence of major geomagnetic storm given the i^{th} observation of the solar variable

$\boldsymbol{b_j}$ **(*j*=0 to *J*)** = model parameters (regression coefficients)

$\mathbf{x_{ij}}$ **(*i*=0 to *I*; *j*=0 to *J*)** = independent variables

I* and *J = total number of observations

(Srivastava 2005)

Application of the model to the data

(a) Solar Parameters: Inputs to the logistic regression model

1.Flare X-class classification:

C - class flare code 0.1
M - class flare code 1.0
X - class flare code 10.0

Flare Impact parameter = Flare-class · flare duration (min)

2. Source Location:

(a) Latitude: North (+), South (-)
(b) Longitude: East (+), West (-)

3. Neutral line orientation: . the angle is measured from North anticlockwise.

4. Initial speed of CME:

Either projected Speed (V_{proj}); Radial Speed (V_{rad}) or True speed (V_{tt})

Application of the model to the data

Model Equation

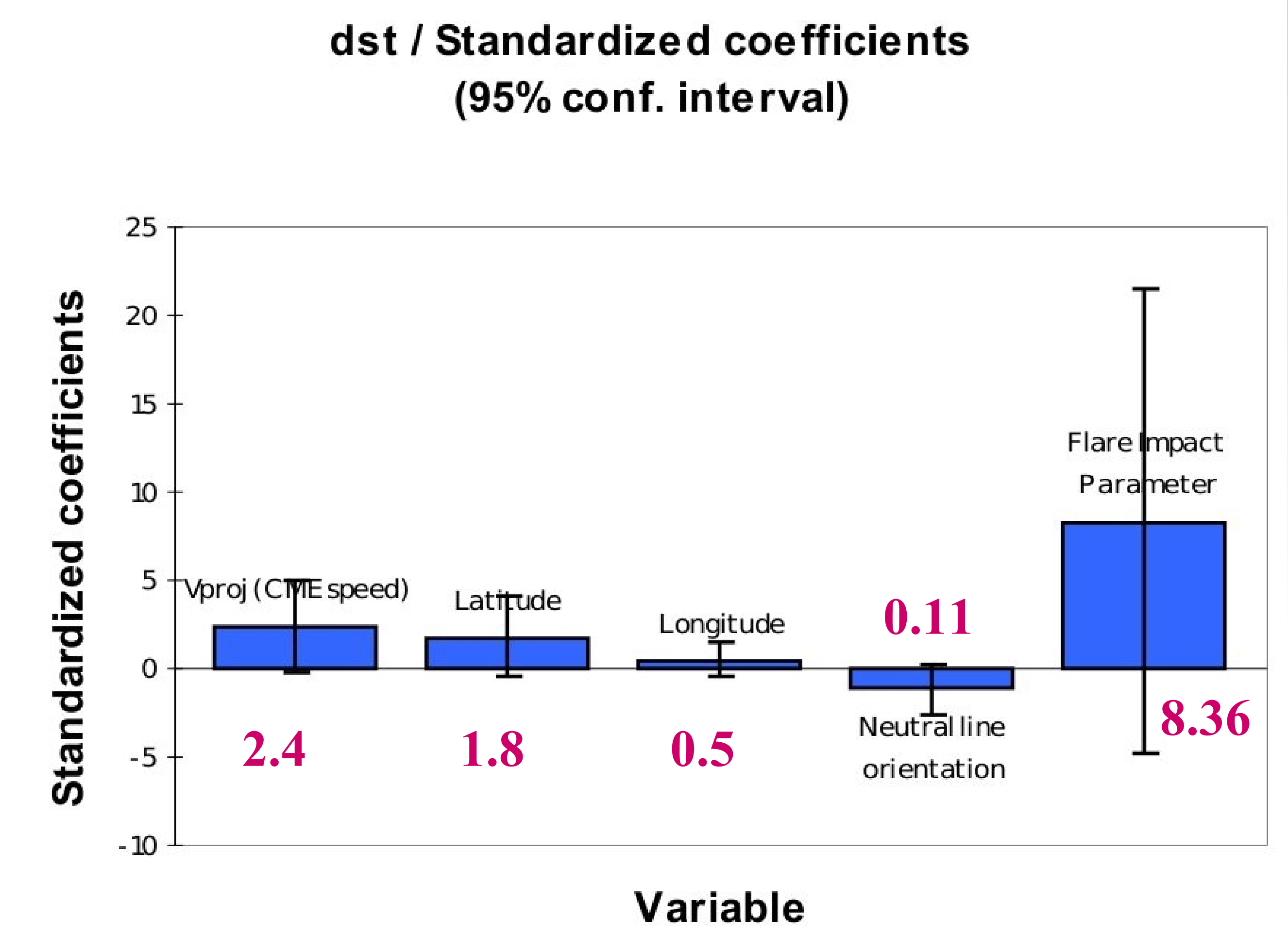
$$\Pi_i = 1/(1+e^{-Z_i})$$

$$Z_i = -10.06 + 7.25 \cdot 10^{-03} * V_{CME} + 0.23 \cdot Lat + 3.93 \cdot 10^{-02} \cdot Lon - 4.03 \cdot 10^{-02} \cdot (NL\ orientation) + 4.88 \cdot 10^{-03} \cdot (Flare\ impact\ param)$$

$\prod_i$ = Pred(Dst)

V_{CME} = CME speed

Results



Standardized coefficients are used to compare the relative weights of the variables. The higher the absolute value of a coefficient, the more important the weight of the corresponding variable.

Prediction

Data Sets	Observed	Predicted	% correct Prediction
Intense Storms	14	13	92.86%
Major Storms	11	10	90.91%

Conclusions

(1) Prediction is better with initial speeds input taken as Vproj compared with Vtt and Vrad.

(2) The most significant solar input parameter to the model (amongst the chosen parameters/variables) is Duration times X-ray class

(3) This is followed by projected speeds of CMEs, latitude, longitude of the source regions of CMEs.

(4) The neutral-line orientation has hardly any influence on strength of strong storms.