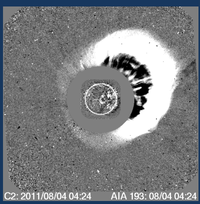
Forbush decrease prediction based on remote solar observation

M. Dumbović, B. Vršnak, J. Čalogović - Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia
Correspondence: mdumbovic@geof.hr

Europska Unija
Ulaganje u budućnost
Projekt je sufinancirala Europska Unija iz Europskog socijalnog fonda

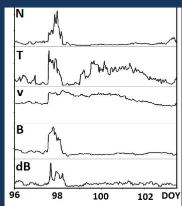
MOTIVATION

Forbush decreases are short term depressions in the galactic cosmic ray flux observed at Earth and in the interplanetary space, caused by interplanetary counterparts of coronal mass ejections (CMEs).



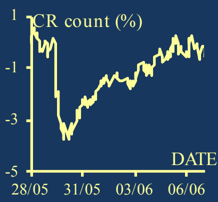
Coronal mass ejection (CME) and associated solar flare detected by LASCO coronagraph onboard SOHO spacecraft and AIA imager onboard SDO spacecraft, respectively

Forecast: ~1 day in advance



Interplanetary coronal mass ejection (ICME) identified using in situ measurements of solar wind density, temperature and speed, as well as magnetic field strength and fluctuations detected by SWEPAM and MAG detectors onboard ACE spacecraft

Forecast: ~1 hour in advance



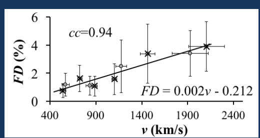
Forbush decrease identified using ground-based neutron monitor measurements of the relative pressure corrected cosmic ray flux

The relationship between ICMEs and Forbush decreases enables using real-time, near-Earth *in situ* measurements as a forecast of the approaching ICME-related Forbush effects 1 hour in advance.

We employ remote solar observations of CMEs and the associated solar flares to forecast the approaching ICME-related Forbush effects 1 day in advance.

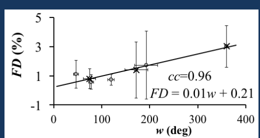
STATISTICAL ANALYSIS

A statistical analysis was performed on a sample of 187 CMEs with associated solar flares and Forbush decreases. Due to large scatter of the data, measurements were grouped and averaged and a method of overlapping bins was used to obtain relations between different CME/flare parameters and Forbush decrease magnitude (FD(%)).



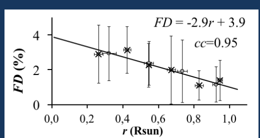
CME speed, v

FD(%) was found to be related to the 1st order (linear) CME speed measured in the LASCO field of view:
FD(%) is larger for faster CMEs



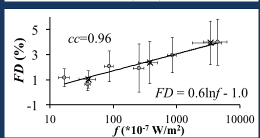
CME apparent width, w

FD(%) was found to be related to the apparent CME width measured in the LASCO field of view:
FD(%) is larger for wider CMEs



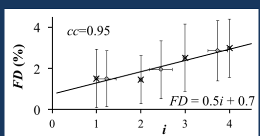
CME/flare source position, r

FD(%) was found to be related to the source position of the associated flare on the solar disc, namely to the distance from the center of the solar disc (in solar radii):
FD(%) is larger for flares originating close to the center of the solar disc



Solar flare Soft X-ray peak intensity, f

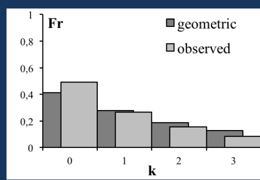
FD(%) was found to be related to the Soft X-ray peak intensity measured by GOES satellite:
FD(%) is larger for stronger flares



CME-CME interaction level, i

FD(%) was found to be related to the parameter "interaction level", derived using CME timing, width and source position, which describes the likeliness of interaction with another CME:
FD(%) is larger for interacting/multiple CMEs

THE MODEL



The distribution of observed Forbush decrease magnitudes (FD(%)) resembles the geometric distribution when the following association is made:

k = 0	⟷	FD(%) < 1
k = 1	⟷	1 < FD(%) < 3
k = 2	⟷	3 < FD(%) < 6
k = 3	⟷	FD(%) > 6

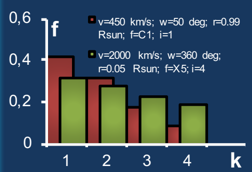
For a CME-flare event a probability distribution is constructed for EACH of the 5 solar parameters (α=v,w,r,f,i) via geometric distribution using the correlations obtained with the statistical analysis

$$P_\alpha(k) = p_\alpha (1 - p_\alpha)^k$$

$$p_\alpha = [1+FD_{MEAN}(\alpha)]^{-1}$$

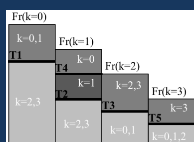
A combined probability distribution is a union of each of the 5 probability distributions:

$$P(k) = P\left(P_v(k) \cup P_w(k) \cup P_r(k) \cup P_f(k) \cup P_i(k) \right)$$



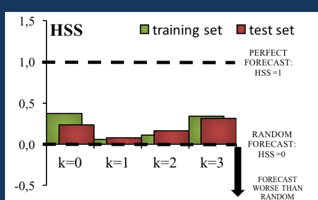
A constructed probability distribution changes with the solar parameters – for favorable solar parameters probability is increased for larger k, i.e. larger Forbush decrease magnitudes. However, regardless of the solar parameters the probability distribution always peaks for k=0, i.e. there is always the highest probability that there will be no Forbush effect.

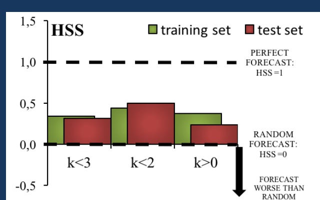
Therefore, thresholds (T1-T5) have to be set (derived based on the sample) and some conditions imposed on the probability distribution to forecast more (k=0,1,2,3) or less (k>0,k<2, k<3) specific Forbush decrease magnitudes



EVALUATION

Evaluation is performed on the **training set** (187 CME-flare-FD sample used for the statistical analysis) and **test set** (independent sample of 42 CME-flare-FD events).





Heidke Skill Score (HSS) reveals that Forbush decrease prediction is better for less specific forecast (right image) and is best for predicting whether **FD > 3%.**

SUMMARY & CONCLUSION

AIM: employ remote solar observations for Forbush effect forecast
METHOD: statistical analysis, distribution fitting
THE MODEL: empirical, statistical, probabilistic
INPUT: remote solar observations of CME and associated solar flare
OUTPUT: expected Forbush decrease magnitude (FD(%)) range
DRAWBACKS: as the forecast tends to be more specific it is less reliable
ADVANTAGES: early warning, input is not necessarily satellite-dependent

PAPER: Dumbović, M., Vršnak, B., and Čalogović, J.: Forbush Decrease Prediction Based on Remote Solar Observations, 2016, Solar Physics, Volume 291, Issue 1, pp. 285-302

ONLINE TOOL: http://oh.geof.unizg.hr/FDFT/fdft.php