

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

THE HVAR OBSERVATORY CME-EFFECTIVENESS FORECAST TOOLS



Dumbović, M., Vršnak, B., Čalogović, J.

Hvar Observatory, Faculty of Geodesy,

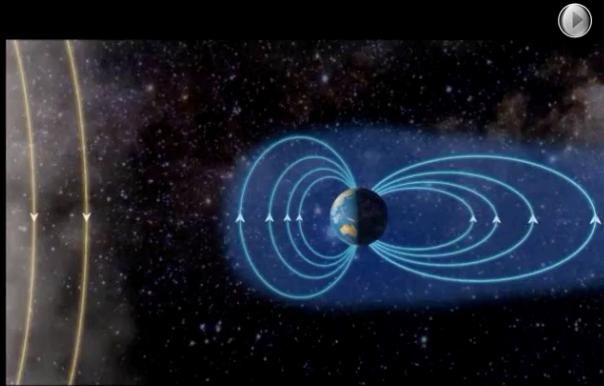
University of Zagreb, Croatia

GEOMAGNETIC STORMS

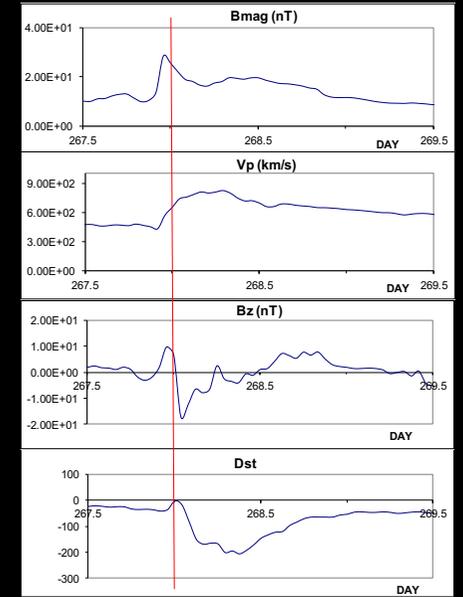
Geomagnetic disturbances
(detected by magnetometers at
Earth)

Currents induced by charged
particles injected due to magnetic
reconnection between ICME &
geomagnetic field

ICME B_s and v crucial! ($E=B_s v$)



Animation: www.forskning.no (University of Osb)



In situ/ACE + Dst indeks/Kyoto

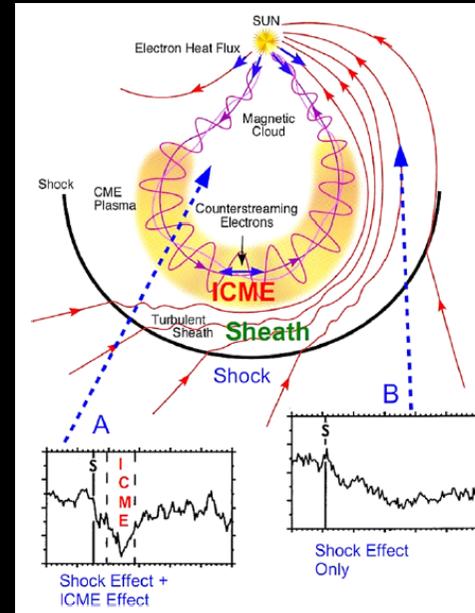
Dungey (1961), Koskinen&Huttunen (2006),
Verbanac et al (2013)

FORBUSH DECREASES

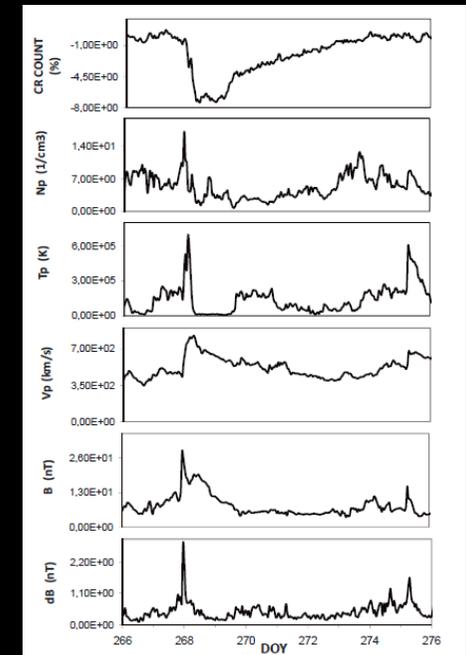
Short term decreases in galactic cosmic ray
(GCR) flux (typical duration several days,
typical magnitude several %)

Due to interaction of GCRs with
shock/sheath region and CME/ejecta region
(different mechanisms)

Increased B and v crucial!



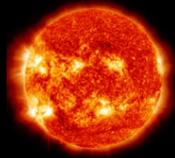
Richardson & Cane (2011)



Dumbović et al (2012)

Dumbović et al (2011), Richardson & Cane (2011),
Dumbović et al (2012), Belov et al (2014)

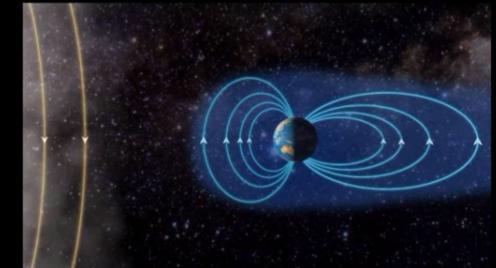
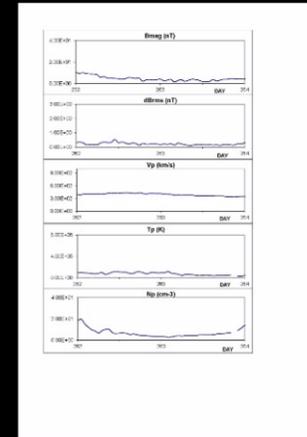
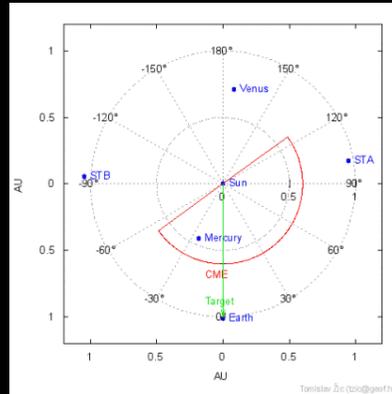
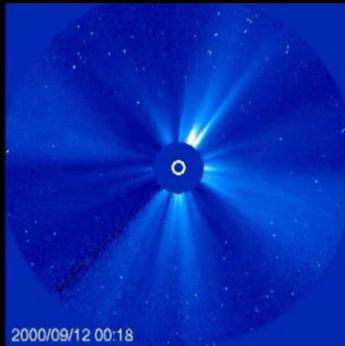
How to predict CME space weather effects?



150 000 000 km



1500 000 km



CME detection:
Initial conditions



Modeling of CME
propagation & evolution



Prediction of ICME
arrival and near-Earth
properties



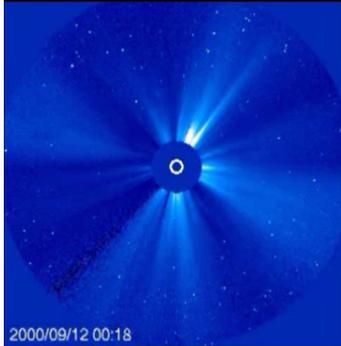
Modeling of
geomagnetic storms
and Forbush
decreases



~ 1 day

~ 1 h

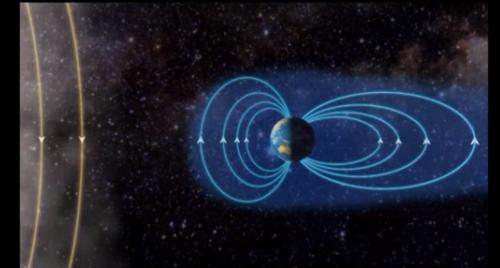
How to predict CME space weather effects?



Statistical relations



Empirical probabilistic model



CME detection:
Initial conditions



Modeling of
geomagnetic storms
and Forbush
decreases



~ 1 day

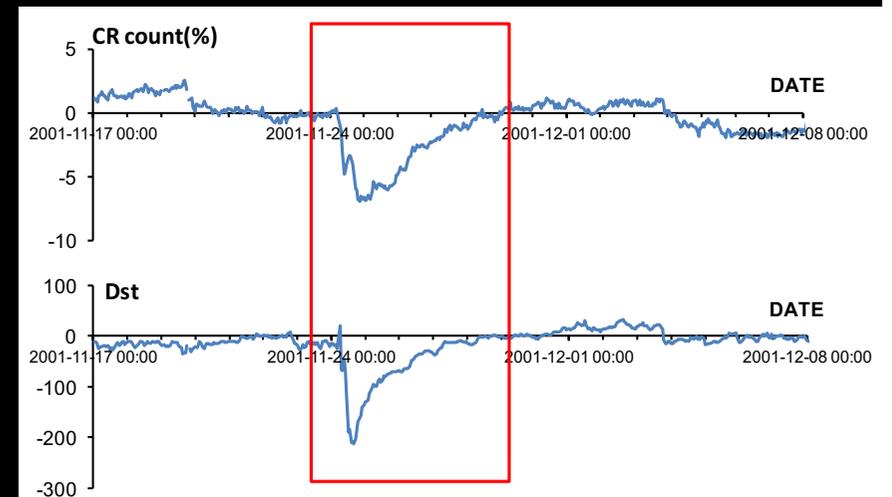
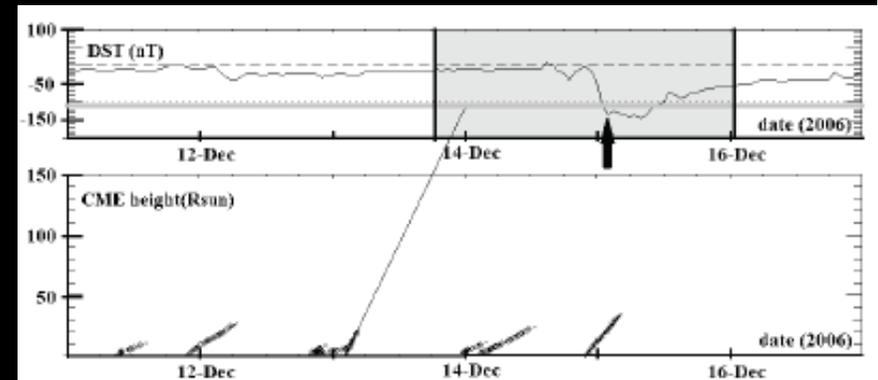
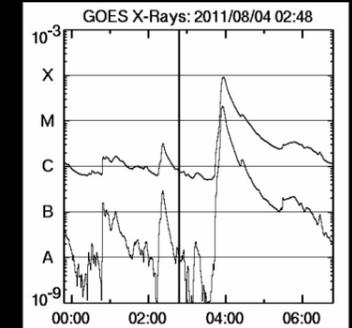
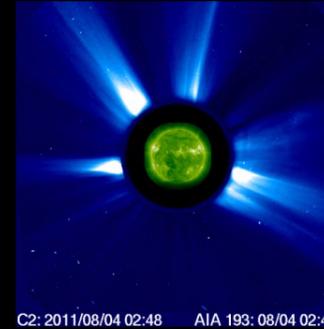
METHOD OVERVIEW:

Make a sample of events

Select CMEs and associated flares

Associate geomagnetic storms (GMS)

Associate Forbush decreases (FD)



METHOD OVERVIEW:

Make a sample of events



Select CMEs and associated flares

Associate geomagnetic storms (GMS)

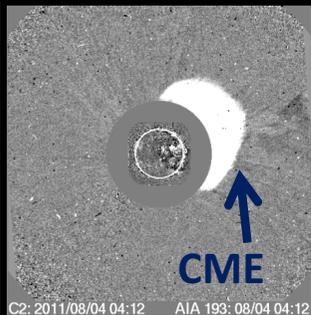
Associate Forbush decreases (FD)

Statistical analysis

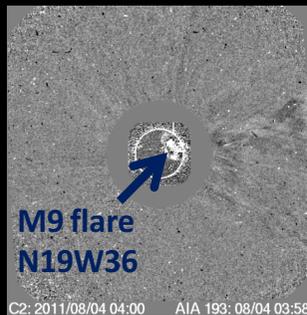
Select key CME properties

guided by previous studies:

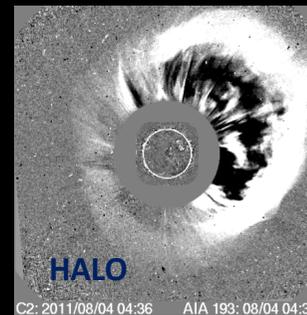
e.g. Zhang et al. (2003), Srivastava & Venkatakrisnan (2004), Srivastava (2005), Gopalswamy et al. (2007), Zhang et al. (2007), Richardson & Cane (2011), Kim et al. (2012)



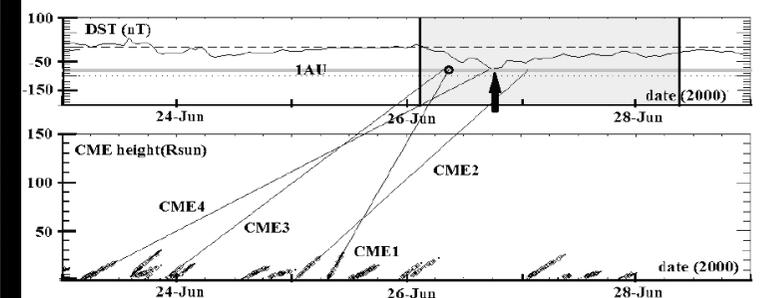
Associated flare X-ray flux peak and source position



CME speed



CME apparent width



CME-CME interaction parameter (likeliness of CME-CME interaction)

METHOD OVERVIEW:

Make a sample of events



Select CMEs and associated flares

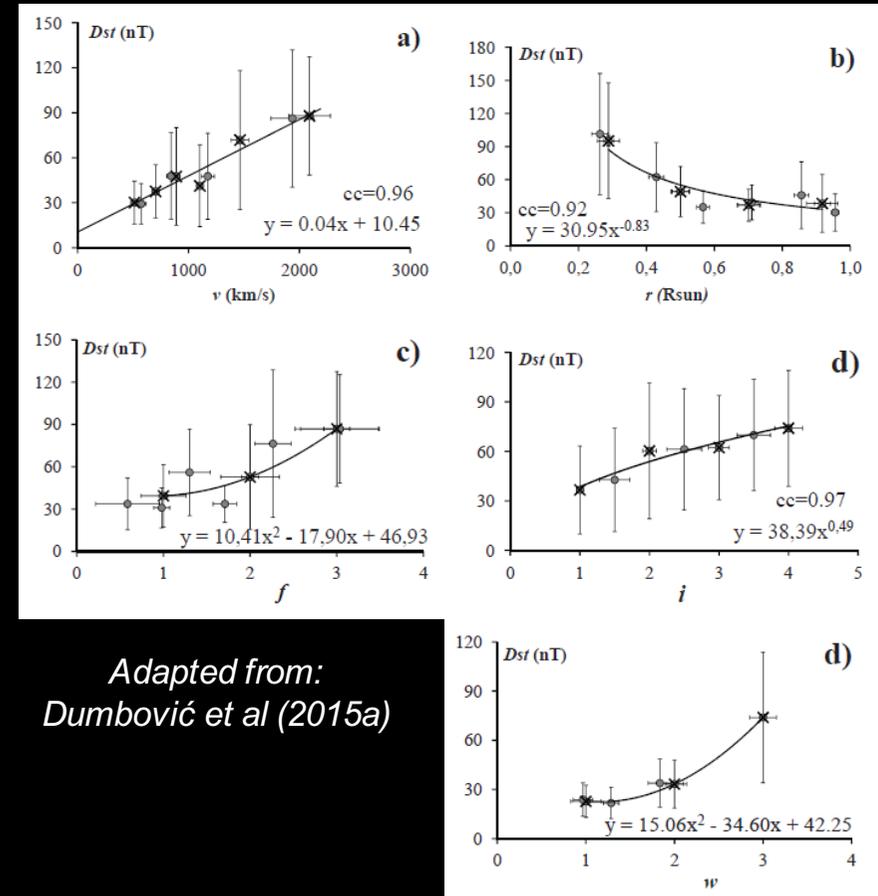
Associate geomagnetic storms (GMS)

Associate Forbush decreases (FD)

Statistical analysis

Select key CME properties

Find CME-GMS relations



Adapted from:
Dumbović et al (2015a)

STRONGER STORMS
ARE CAUSED BY:

faster CMEs
wider CMEs
interacting CMEs
central CME/flares
stronger flares

METHOD OVERVIEW:

Make a sample of events



Select CMEs and associated flares

Associate geomagnetic storms (GMS)

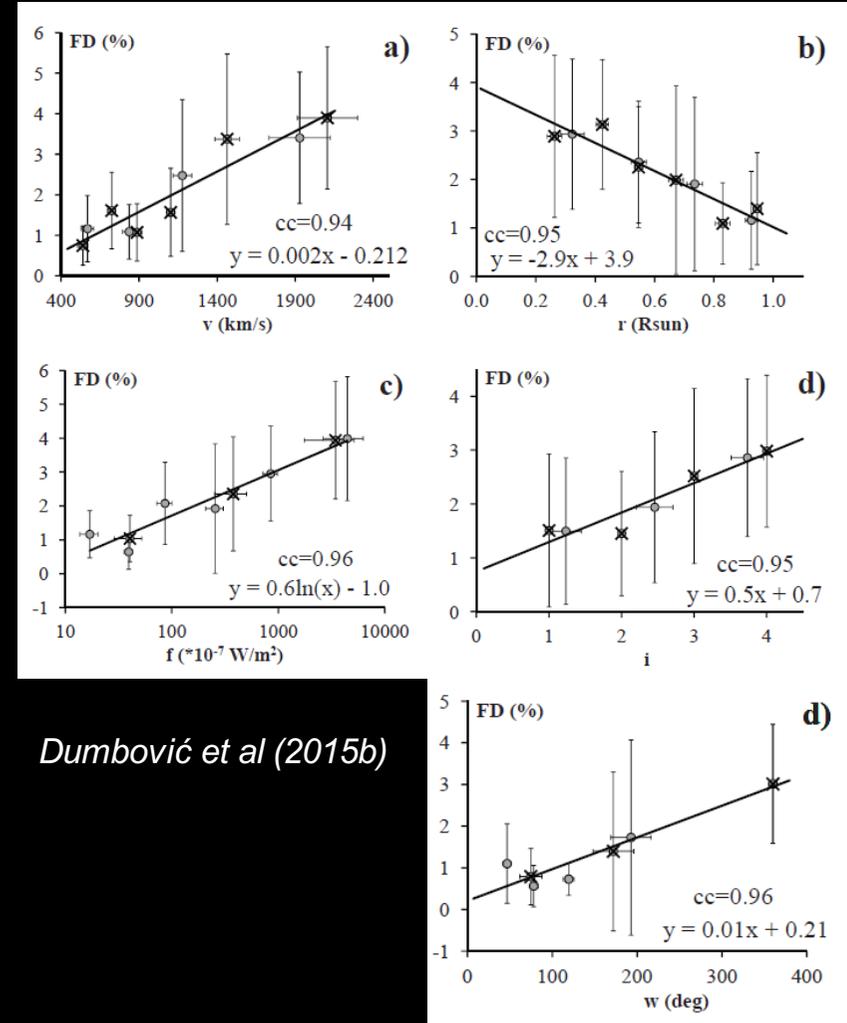
Associate Forbush decreases (FD)

Statistical analysis

Select key CME properties

Find CME-GMS relations

Find CME-FD relations



DEEPER FDs ARE
CAUSED BY:

faster CMEs
wider CMEs
interacting CMEs
central CME/flares
stronger flares

METHOD OVERVIEW:

Make a sample of events



Select CMEs and associated flares

Associate geomagnetic storms (GMS)

Associate Forbush decreases (FD)

Statistical analysis



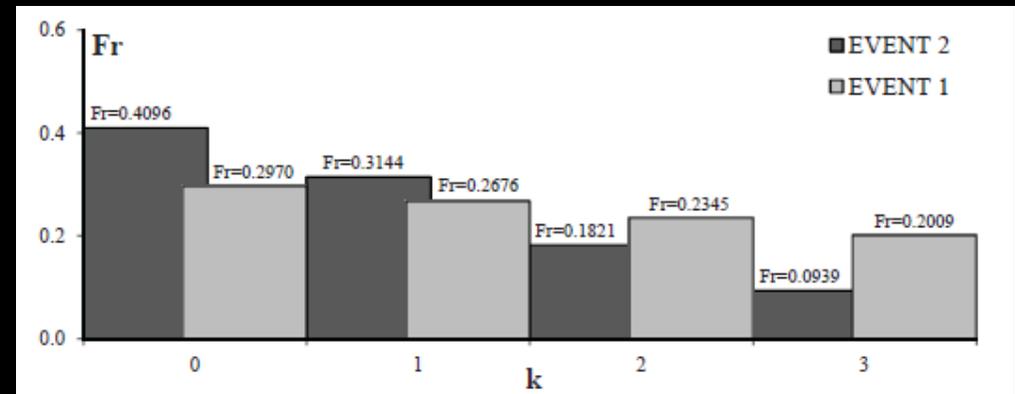
Select key CME properties

Find CME-GMS relations

Find CME-FD relations

Model

Employ the results of the statistical analysis



- 1) Construct probability distribution which changes from one event to another depending on the input parameters
- 2) Estimate the expected level based on the probability distribution

www.oh.geof.unizg.hr

oh.geof.unizg.hr

Apple iCloud Google

Hvar Observatory - Space weather tools Forbush Decrease Forecast Tool (FDFT) CME Geo-effectiveness Forecast Tool

CME Geo-effectiveness Forecast Tool (CGeFT)

Model input Documentation

CME speed, v (in km/s): ? not available

CME/flare source position radius, R_s (in solar radii): ? not available

CME apparent width, w :

Solar flare x-ray class, f :

CME-CME interaction level, i :

Calculate Reset!

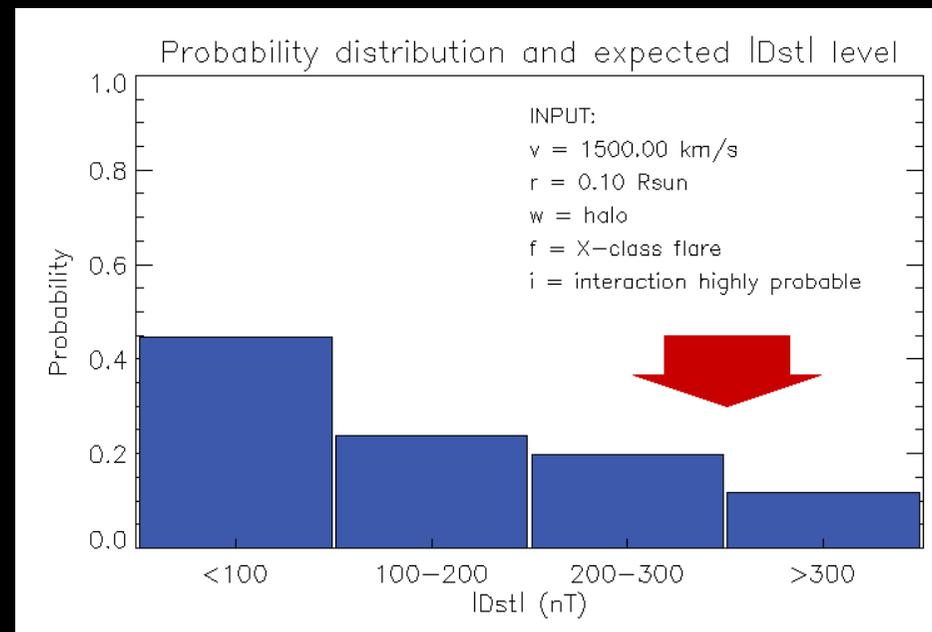
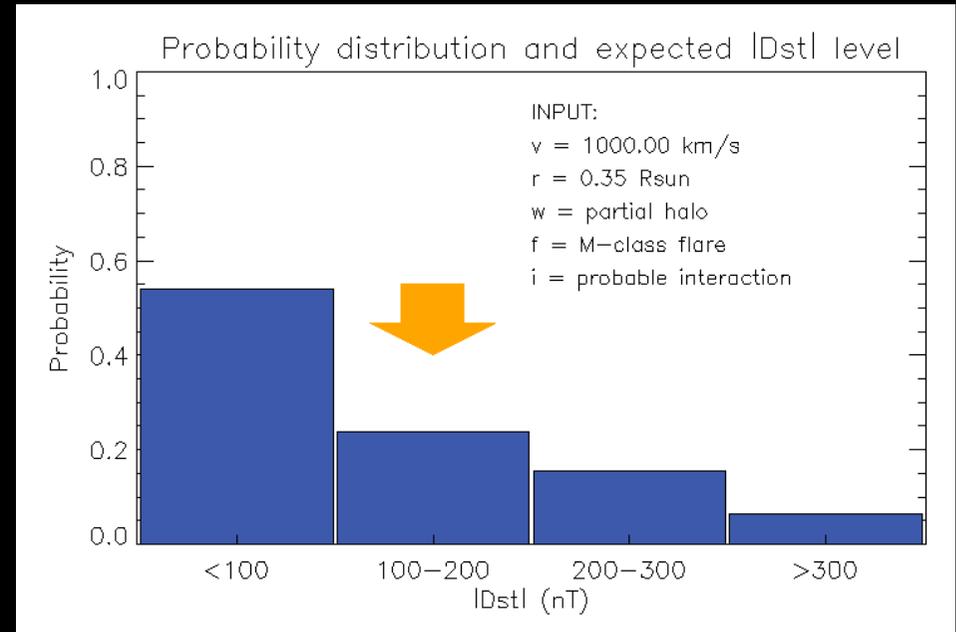
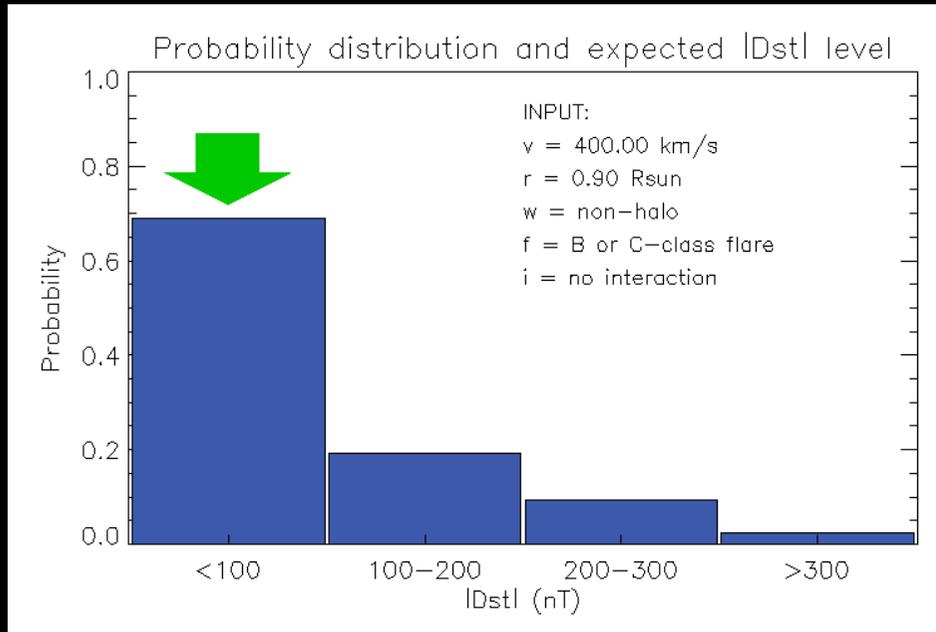
CME geo-effectiveness forecast tool has performed **265** successful calculations (since 10.3.2014).



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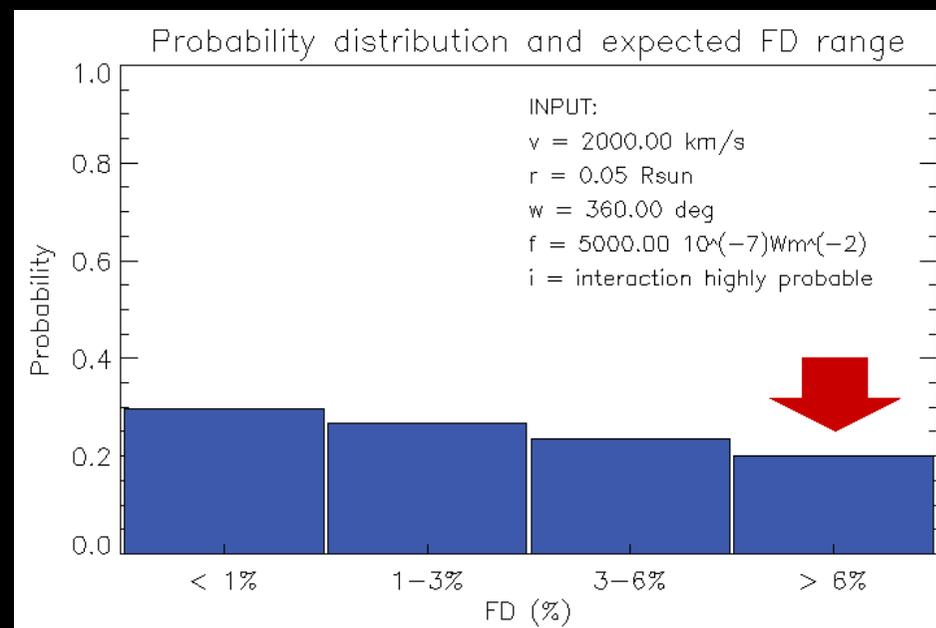
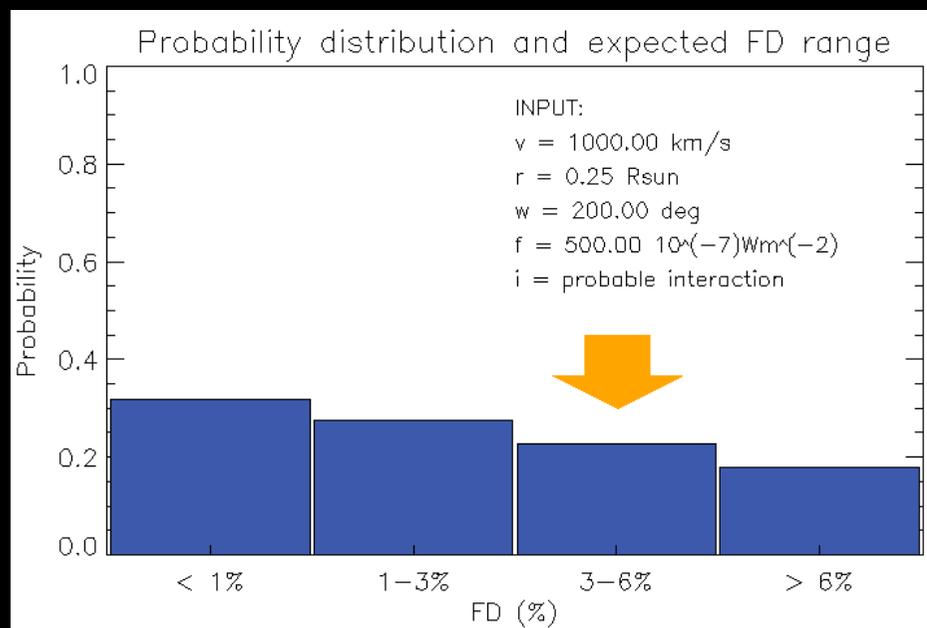
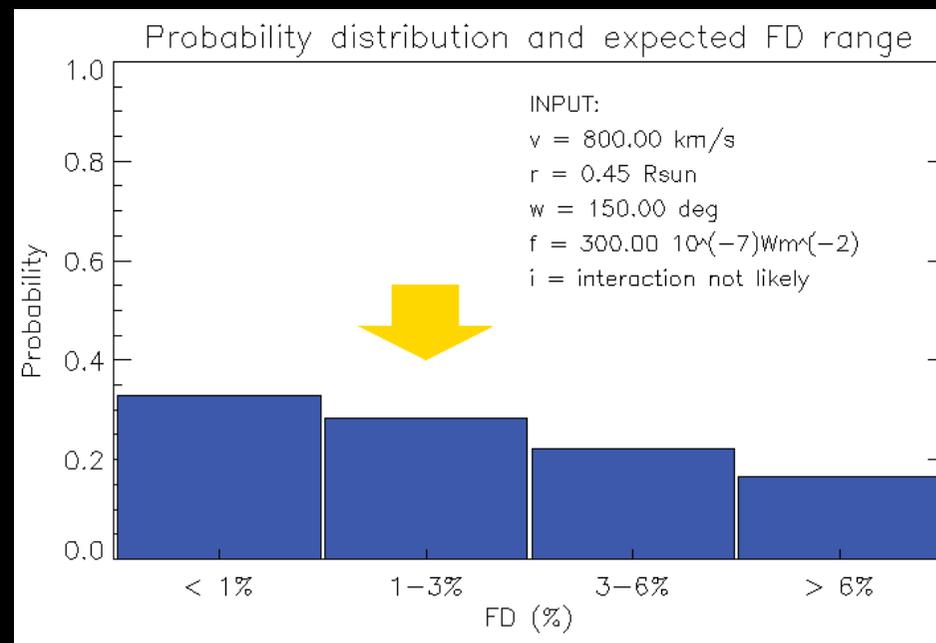
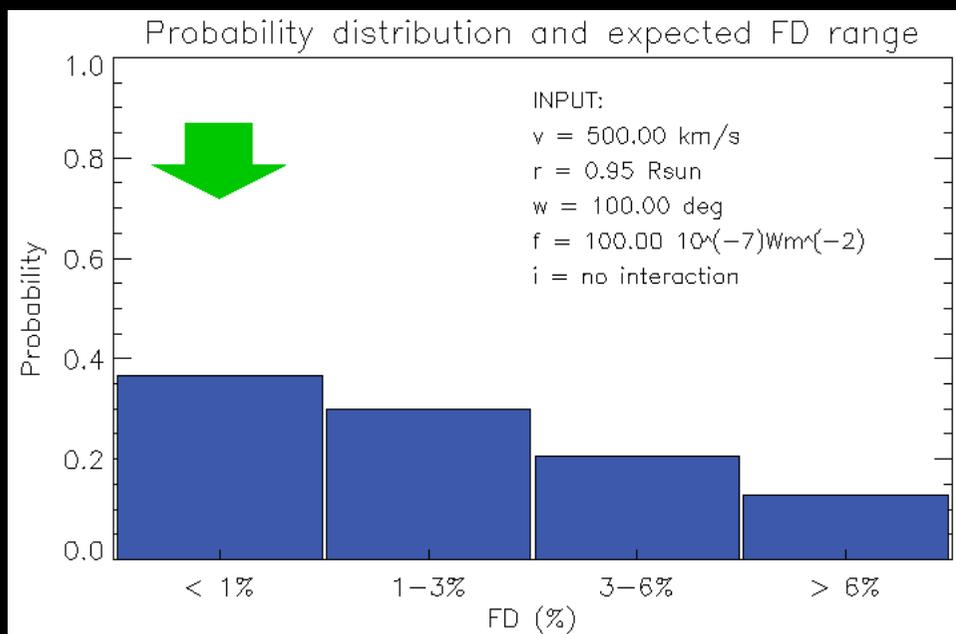
CME Geo-effectiveness Forecast Tool (CGeFT)

<http://oh.geof.unizg.hr/CGEFT/cgeft.php>



Forbush Decrease Forecast Tool (FDFT)

<http://oh.geof.unizg.hr/FDFT/fdft.php>



evaluation

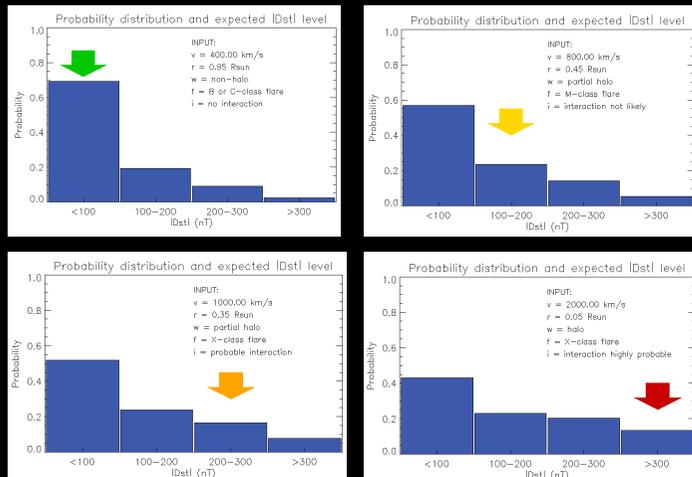
EVALUATION MEASURE – HEIDKE SKILL SCORE (meteorology!):
 $-\infty < \text{HSS} < 1$

HSS=0 as good as a random guess

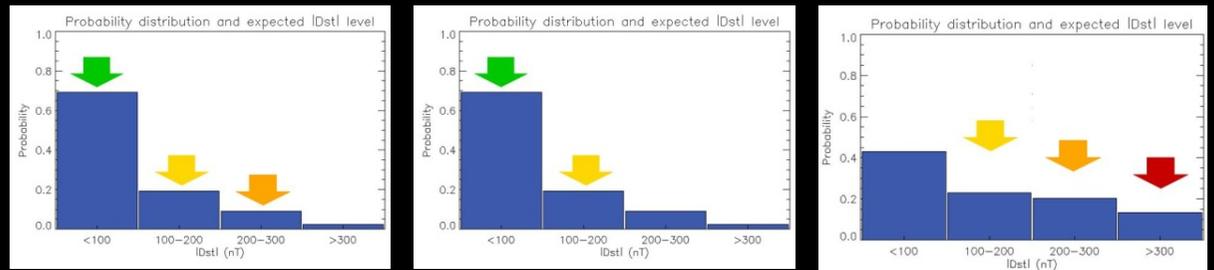
HSS<0 worse than a random guess

HSS>0 better than a random guess

HSS=1 perfect forecast



	storm	FD
no effect	0.2	0.24
medium	0.08	0.08
strong	0.36	0.16
intense		0.31



no intense effect	FD < 6%	0.31
no strong or intense effect	FD > 3%	0.5
anny effect	FD > 1%	0.24

e.g. human forecast (SIDC*) whether or not there will be storm, HSS=0.34
 Devos et al (2014); Solar Influences Data Center (at ROB, BEL)

The 1st version of CGeFT implemented in the COMESEP alert system

(check out the poster by Srivastava et al: "Validation of the CME Arrival Time and Geomagnetic forecast alerts under COMESEP")

Alert Viewer Current time: 25-03-2015 10:42

	Latest issued alert	Impact risk
Geomagnetic Storm Alert	24/03/15 19:49	<ul style="list-style-type: none"> The risk level for a CME geomagnetic storm is MEDIUM following the observation of a CME that erupted at 08:24 on 2015-03-24 UTC. The risk level results from the following forecasted parameters: 1) occurrence probability: LIKELY 2) storm level: MINOR The risk level for geomagnetic storm the next 24 hours is Low The risk level for a CME geomagnetic storm is MEDIUM following the observation of a CME that erupted at 03:24 on 2015-03-20 UTC. The risk level results from the following forecasted parameters: 1) occurrence probability: VERY UNLIKELY 2) storm level: STRONG
SEP Proton Storm Alert > 10 MeV	No alert since 7 days	Nothing to report
SEP Proton Storm Alert > 60 MeV	No alert since 13 days	Nothing to report

Legend: ★ ... an alert has been issued
 ○ ...risk impact (timing and level, ● low, ● medium, ● high, ● extreme)
 Click on the icons to see alert details

Register for COMESEP alerts

	22 MAR 12:00	23 MAR 12:00	24 MAR 12:00	25 MAR 12:00	26 MAR 12:00	27 MAR 12:00	28 MAR 12:00	29 MAR 12:00
Flare		★		★				
CME				★ ★				
SEP								
Geomagnetic activity	●	●		★ ●	●		●	

Publication:

Dumbović et al. (2015a), Sol.Phys.
 Dumbović et al (2015b), Sol. Phys.
 Dumbović PhD thesis (2015)

Available at: oh.geof.unizg.hr

Acknowledgements:

The work leading to this research was (partly) funded by:

EU FP7 project COMESEP (Coronal Mass Ejections and Solar Energetic Particles)

HRZZ project SOLSTEL (Solar and Stellar variability)

HEP (national) project "Predviđanje učinaka Sunčevih koroninih izbačaja na Zemljino magnetsko polje"

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Thank you for your attention!

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