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Statistical model for predicting arrival and geoeffectiveness of CMEs based on near realtime remote solar observations

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Summary

What?: *CME geomagnetic forecast tool*

Context: *integrated in COMESEP alert system (www.comesep.eu/alert)*

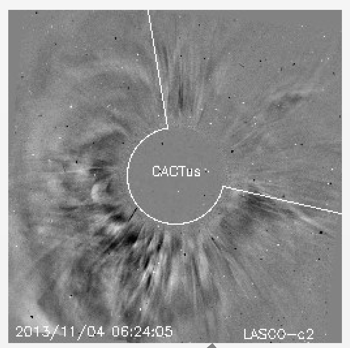
Input: *positional and physcial parameters from detection algorithms CACTus, flaremail and SolarDemon*

Output: *estimation of CME arrival, storm impact and duration*

How?: *statistical model developed based on CME event lists*

Process

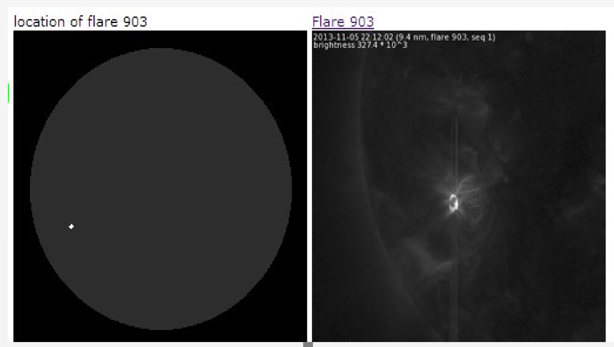
CACTus[1]



CME speed

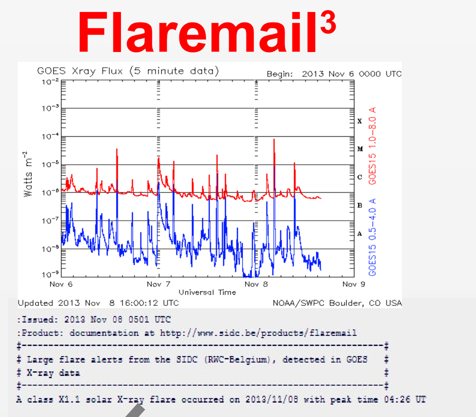
CME width

Solar Demon[2]



flare position
(of associated flare)

Flaremail[3]



flare strength
(of associated flare)

CME Geomagnetic Forecast Tool (CGFT):

estimate CME geomagnetic storm

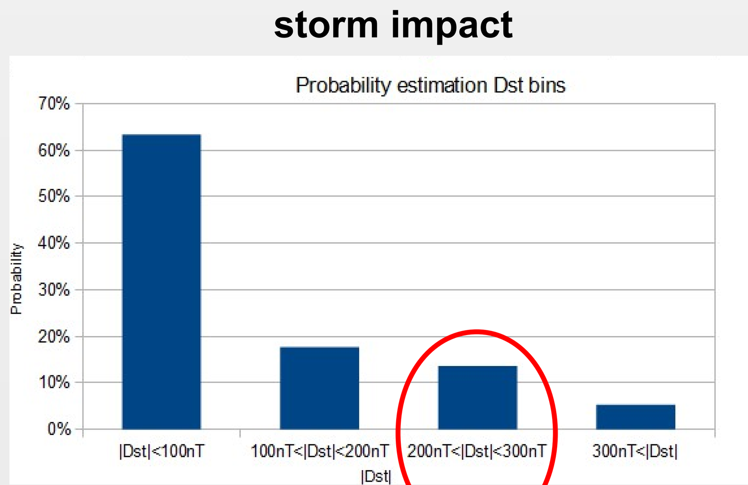
CME arrival probability
(using only flare position)

60%

storm duration

30 hours

storm impact



Extra notes on CME estimation:
- time of CME arrival: estimated by drag-based model (**DBM**)[6]
- **Geomag24**: estimation of risk level for next 24h
- all integrated in **COMESEP alert system**[7]

	CME arrival	storm level (impact)[4]	storm duration
input parameters	• flare position	• CME width • CME speed • flare strength • flare position	• estimated storm level • season (see semi-annual variations[5])

CME geomagnetic risk matrix

On-going (100%)	L	M	H	H	E	E
Very likely (90-100%)	L	M	H	H	E	E
Likely (90-100%)	L	M	M	H	H	E
Possible (40-70%)	L	L	M	M	H	E
Unlikely (10-40%)	L	L	M	M	H	H
Very unlikely (0-10%)	L	L	L	M	M	H
Storm level	None	Minor	Moderate	Strong	Severe	Extreme
|Dst| (nT)	0-50	50-100	100-200	200-300	300-400	>400

Risk = Likelihood x Impact	
E	Extreme Risk
H	High Risk
M	Moderate Risk
L	Low Risk

Data

All data: CMEs from SOHO/LASCO CME catalog[9], possibly relating to an arriving ICME noted in ICME catalog[10] or with signatures of ICME arrival in solar wind data[11,12]

Training data for model setup of CME arrival: 237 halo CMEs

Training data for model setup of storm impact: 211 flare-associated CMEs, speed ≥ 400 km/s

Test data for model evaluation: 200 CMEs, speed ≥ 400 km/s, width ≥ 120°

Note: test data have lower % of arrival and lower % of (moderate) storms

Forecast verification

Verification measures for a binary event

Contingency table:

		Observation	
		Yes	No
Forecast	Yes	a=#hits	b=#false alarms
	No	c=#misses	d=#correct rejections

Probability of Detection (**POD**) = *a/(a+c)*
Proportion Correctness (**PC**) = *(a+d)/n*
Bias (measure for over- or underestimation) = *(a+b)/(a+c)*
Heidke Skill Score (**HSS**) = *(PC-E)/(1-E)*, with *E*: PC for random forecast
True Skill Statistic (**TSS**) = *(ad-bc)/ ((a+c)(b+d))*

Range of POD, PC: [0,1]; of Bias: [0,∞]; of HSS, TSS: [-1,1]

Arrival estimation

- setting threshold on 40% for arrival leads to best performance (POD and HSS/TSS on test data)

	training data			test data		
threshold on prob	40%	50%	60%	40%	70%	90%
n	237	237	237	200	200	200
hits	0,51	0,40	0,25	0,17	0,07	0,07
false alarms	0,35	0,24	0,11	0,50	0,33	0,27
misses	0,05	0,16	0,31	0,03	0,12	0,13
correct rejections	0,09	0,20	0,33	0,32	0,48	0,54
events	0,56	0,56	0,56	0,19	0,19	0,19
POD	**0,90**	**0,71**	**0,45**	**0,87**	0,39	0,34
PC	0,59	0,60	0,59	0,48	0,56	0,60
bias	1,53	1,14	0,64	3,47	2,13	1,76
HSS	**0,11**	**0,17**	**0,20**	**0,13**	-0,01	0,01
TSS	**0,10**	**0,17**	**0,21**	**0,26**	-0,01	0,01

Impact estimation

- tendency to overestimate impact, but ...
- several (moderate) storms are missed; e.g. POD is only 0.56 on training set

	training data		test data	
threshold on |Dst|	100 nT	200 nT	100 nT	200 nT
n	211	211	200	200
hits	0,07	0,04	0,01	0,00
false alarms	0,22	0,25	0,09	0,10
misses	0,05	0,01	0,03	0,00
correct rejections	0,66	0,70	0,88	0,91
events	0,12	0,05	0,04	0,00
POD	**0,56**	**0,80**	**0,25**	
PC	0,73	0,74	0,89	0,91
bias	2,44	6,10	2,38	
HSS	**0,19**	**0,16**	**0,10**	
TSS	**0,31**	**0,54**	**0,16**	

Future work

- improve probability estimation model
- improve conversion of estimated probability distribution to impact
- evaluate and improve estimation of storm duration

References

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