

Technical University of Denmark



## 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

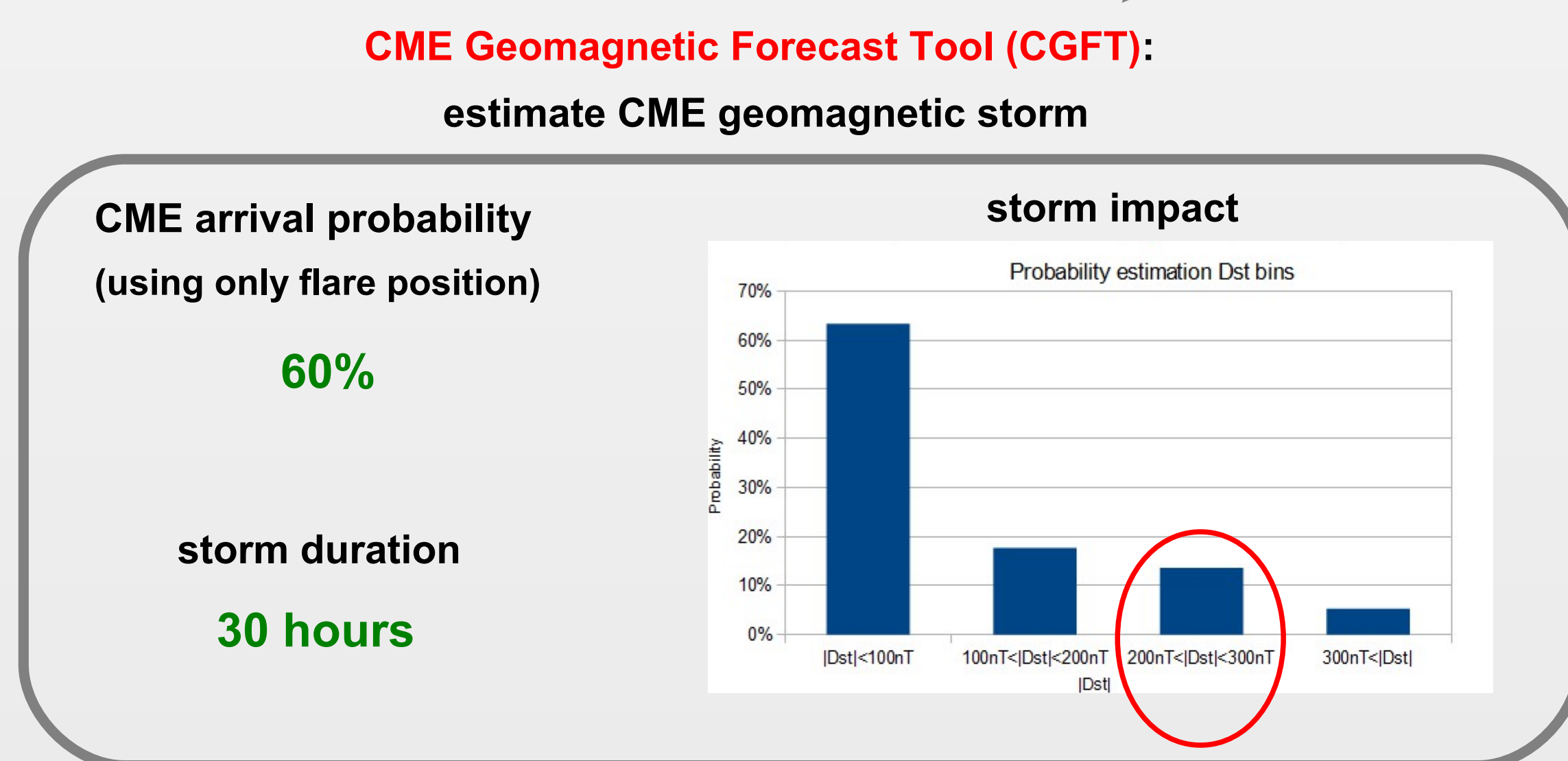
**Context:** integrated in COMESSEP alert system ([www.comesep.eu/alert](http://www.comesep.eu/alert))

**Input:** positional and physical 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



### Extra notes on CME estimation:

- time of CME arrival: estimated by drag-based model (DBM)<sup>6</sup>
- Geomag24: estimation of risk level for next 24h
- all integrated in COMESSEP alert system<sup>7</sup>

input parameter s	CME arrival	storm level (impact) <sup>4</sup>	storm duration
• flare position	• flare position	• CME width • CME speed • flare strength • flare position	• estimated storm level • season (see semi-annual variations <sup>5</sup> )

### CME geomagnetic risk matrix

Risk = Likelihood x Impact	None	Minor	Moderate	Strong	Severe	Extreme
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

## 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  
 $(ad-bc)/((a+c)(b+d))$

True Skill Statistic (TSS) =

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		
	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	<b>0,90</b>	<b>0,71</b>	<b>0,45</b>	<b>0,87</b>	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	<b>0,11</b>	<b>0,17</b>	<b>0,20</b>	<b>0,13</b>	-0,01	0,01
TSS	<b>0,10</b>	<b>0,17</b>	<b>0,21</b>	<b>0,26</b>	-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	
	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	<b>0,56</b>	<b>0,80</b>	<b>0,25</b>	
PC	0,73	0,74	0,89	0,91
bias	2,44	6,10	2,38	
HSS	<b>0,19</b>	<b>0,16</b>	<b>0,10</b>	
TSS	<b>0,31</b>	<b>0,54</b>	<b>0,16</b>	

## Future work

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

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## Data

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

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

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

Test data for model evaluation: 200 CMEs, speed  $\geq 400$  km/s, width  $\geq 120^\circ$

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