The CME geomagnetic forecast tool (CGFT)

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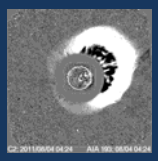
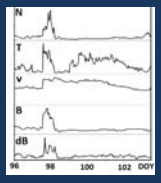
MOTIVATION



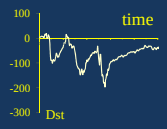
Coronal mass ejection (CME) and associated solar flare detected by LASCO coronagraph onboard SOHO spacecraft and AIA imager onboard SDO spacecraft, respectively

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



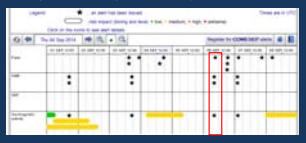
Geomagnetic storm observed in the Dst index, derived from ground-based measurements of the geomagnetic field (Kyoto WDC for Geomagnetism)

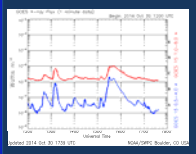
The relationship between ICMEs and geomagnetic storms enables using real-time near-Earth *in situ* measurements as a forecast of the approaching ICME-related geo-effects 1 hour in advance.

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

THE CGFT OPERATIONAL MATRIX (*within COMESEP alert system*)

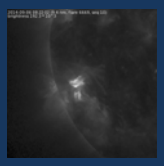
http://comesep.aeronomy.be/alert//





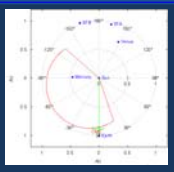
flaremail
Detection of M and X-class flares from GOES

Flaremail + Solar DEMON



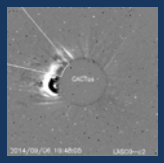
Solar DEMON
"*The Solar Dimming and EUV wave Monitor*" automatic flare detection using SDO/AIA

http://solardemon.oma.be/



DBM
"*Drag-Based Model*" Determines whether CME will arrive and calculates CME arrival time and speed at Earth. Uses input from CACTus and Solar DEMON *Vršnak et al. (2012)*

DBM



CACTus
"*Computer Aided CME Tracking*" Detects autonomously CMEs in SOHO/LASCO

Robbrecht&Berghmans(2004)

CACTus

CGFT
"*The CME Geomagnetic Forecast Tool*"
Uses input from flaremail, Solar DEMON, CACTus and DBM; estimates geomagnetic impact and duration based on three modules:

MODULE I: Estimation of geo-effectiveness of a CME

Calculates probability of a geomagnetic storm based on CME speed, width, solar flare X-ray class and source position, uses probability thresholds to estimate geomagnetic storm level

MODULE II: Estimation of CME arrival probability

Calculates probability of a CME arrival based on latitude and longitude of associated flare, uses probability thresholds to estimate probability of arrival

RISK MATRIX based on modules I and II:

STORM LEVEL (|Dst|)	ARRIVAL PROBABILITY					
	very unlikely (0-10%)	unlikely (10-40%)	possible (40-70%)	likely (70-90%)	very likely (90-100%)
SEVERE (|Dst|>300)	MODERATE	HIGH	HIGH	HIGH	EXTREME
STRONG (|Dst|=200-300)	MODERATE	MODERATE	MODERATE	HIGH	HIGH
MODERATE (|Dst|=100-200)	LOW	MODERATE	MODERATE	MODERATE	HIGH
MINOR (|Dst|<100	LOW	LOW	LOW	MODERATE	MODERATE

MODULE III: Estimation of storm duration

Estimates storm duration based on the estimated storm strength and month of the eruption (seasonal effect)

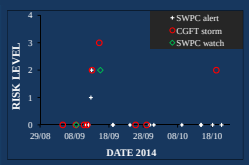
EVALUATION

Comparison was made between CGFT-issued alerts and NOAA SWPC* alerts (magnetometer measurements) and watches (predictions) in September and October 2014.

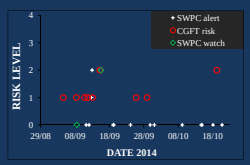
Since two alert systems use different geomagnetic indices, the association between the risk levels of two systems was made.

RISK LEVEL	CGFT storm	CGFT risk	NOAA G scale
0	minor	low	0 or G1
1	moderate	moderate	G2
2	strong	high	G3
3	severe	extreme	G4 | G5

Comparison was made for CGFT-MODULE I (based solely on storm strength prediction) and for combination of CGFT-MODULES I and II (takes into account also probability of arrival).



Only MODULE I of CGFT



Both modules of CGFT

*National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC)

SELF-STANDING CGeFT (help for the forecasters)

The CME geo-effectiveness tool

Self-standing version of CGFT module I – web user interface.

Calculates |Dst| probability distribution based on input of CME speed, width, solar flare X-ray class, source position and CME-CME interaction parameter (*Dumbović et al., 2014*)

Estimates geomagnetic storm risk (uses thresholds on probability distribution)

http://oh.geof.unizg.hr

SUMMARY & CONCLUSION

AIM: employ remote solar observations for geomagnetic storm forecast
METHOD: probability distribution fitting based on the statistical analysis, applying probability thresholds
INPUT: remote solar observations of CME and associated solar flare
OUTPUT: alert of the expected CME-geomagentic impact (low, moderate, high, extreme)
DRAWBACKS: false alarms, depends on CME arrival forecasting tools (for storm onset)
ADVANTAGES: early warning (~1 day), input is not necessarily satellite-dependent (ground-based coronagraphs, H alpha flares)