Validation of the CME Arrival Time and Geomagnetic forecast alerts under COMESEP

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COronal Mass Ejections and Solar Energetic Particles (COMESEP)

= collaborative EU FP7 project (2011-2014)
AIM: produce a fully automatic alert system (runs since 2014)
COMESEP ALERT SYSTEM

First level PRODUCERS

- CACTus (ROB)
- Solar DEMON (ROB)
- Flaremail (ROB)

CONSUMERS/PRODUCERS

- DBM (HVAR)
- Geomag24 (DTU)
- CGFT (ROB)

ALERTS

- Gmag #2
- Gmag #1
- SEP Alert

GLE alert (BIRA-IASB)
SEP forecast (BIRA-IASB)
Computer Aided CME Tracking (CACTus)

- Autonomously detects CMEs using SOHO/LASCO images
- Measures CME apparent width, w and plane-of-the-sky speed, v
- Issues an alert when w>120 degrees
The Solar Dimming and EUV wave Monitor (Solar DEMON) - detects flares automatically and in real time using SDO/AIA data.

Flaremail - issues an alert whenever an M- or X-class flare is detected in the GOES X-ray data.
DRAG BASED MODEL (DBM)

- Assumes that MHD drag governs the propagation of CMEs in IP space
- Calculates ICME arrival time & speed
**CME GEOMAGNETIC FORECAST TOOL (CGFT)**

**CGFT module 1**

Estimates storm risk (4 possible ranges)

Estimates RISK LEVEL based on the RISK MATRIX

When risk level is higher than low issues alert

| STORM LEVEL (|Dst|) | SEVERE (|Dst|>300) | MODERATE | HIGH | MODERATE | HIGH | HIGH | HIGH | EXTREME |
|----------------|----------------|------------|----------|--------|----------|--------|--------|--------|---------|
| STRONG (|Dst|=200-300) | MODERATE | MODERATE | HIGH | HIGH | HIGH |
| MODERATE (|Dst|=100-200) | LOW | MODERATE | MODERATE | MODERATE | HIGH |
| MINOR (|Dst|<100) | LOW | LOW | LOW | MODERATE | MODERATE |

| ARRIVAL PROBABILITY | very unlikely (0-10%) | unlikely (10-40%) | possible (40-70%) | likely (70-90%) | very likely (90-100%) |
1. Detects CME with $w > 150$ degrees; issues alert.
2. Detects M- or X-class flare; associates to CME; issues alert.
3. Triggered by CACTus alert; takes input from CACTus (and Solar DEMON if available); issues alert.
4. Triggered by DBM alert; takes input from CACTus (and Solar DEMON and flaremail if available); calculates Risk level; issues alert.
COMESEP alerts in 2014

Total number of CMEs in 2014 (CACTus catalog): 1855

Number of CMEs with w>120 (CACTus catalog): 98

Total number of issued CGFT alerts: 72

Number of Dst< -100 nT events: 3 (all are forecasted)

Number of CGFT alerts with medium risk: 65

Number of CGFT alerts with high risk: 7

Many low storm risk events were marked as medium risk because of arrival probability!

Number of CGFT alerts with Dst>-100 nT: 47

Number of CGFT alerts with -200nT<Dst<-100 nT: 0

Number of CGFT alerts with -300nT<Dst<-200 nT: 23

Number of CGFT alerts with Dst<-400 nT: 2

Figure 2. CME geomagnetic risk matrix.
Using COMESEP tools with human intervention

**STEP 1: OBSERVERS CROSS-CHECK**
Checking LASCO, SDO and GOES; CME/flare association; using STEREO to discard backsided events

**STEP 2: USING RECENT VERSIONS OF TOOLS**
Recent versions of tools are not automatically implemented in the COMESEP system
Available on-line as self-standing tools:
- Advanced DBM
- Advanced CGFT module 1 (CGeFT)

http://oh.geof.unizg.hr/
Using COMESEP tools with human intervention

Due to interacting CMEs!

- 72 CGeFT CME/flare events
- 66 CGeFT CME/flare events
- 29 advanced DBM misses
- 33 CGeFT alerts
  - 23 alerts Dst>100 nT
  - 8 alerts -200 nT<Dst<-100 nT
  - 3 alerts Dst<-200 nT
- 2 CACTus false detections
## EVALUATION

### OBSERVATION

<table>
<thead>
<tr>
<th>FORECAST</th>
<th>OBSERVATION</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>
| YES      | HITS = CMEs whose geomagnetic storm level was correctly forecasted  
           CGFT – 47  
           CGeFT – 23 |    | \[FALSE ALARMS = CMEs which were forecasted to produce storm stronger than observed  
                                 CGFT – 25  
                                 CGeFT – 10\] |
| NO       | MISS = CMEs which were not forecasted and produced storm OR were forecasted to produce weaker storm than observed  
                 CGFT – 1  
                 CGeFT – 1 |    | \[CORRECT REJECTION = number of CMEs with w>120 which were not forecasted AND did not produce storm (Dst<100)  
                                     CGFT- 26  
                                     CGeFT – 65\] |

- Contingency table -
Evaluation results

- **a)**
  - Best forecast: POD = 1
  - Worst forecast: POD = 0

- **b)**
  - Best forecast: FAR = 0
  - Worst forecast: FAR = 1

- **c)**
  - Overforecast: BIAS > 1
  - Perfect score: BIAS = 1
  - Underforecast: BIAS < 1

- **d)**
  - Perfect forecast: HSS = 1
  - Random forecast: HSS = 0
  - Forecast worse than random: HSS < 0

Sample I and Sample II in CGFT and CGeFT contexts.
Summary

ADVANTAGES:

Fully automatic, no human intervention

System is made of interrelated tools – easy to add, upgrade...

Large number of correct rejections,
System predicts well whether there will be a storm

DRAWBACKS:

Fully automatic, no human (observers) intervention

...but this is not done

... but predictability of actual storm level is questionable (only 3 storms out of which only 1 hit!)

CONCLUSIONS:

human intervention leads to better forecast

Improved automatic system is needed for future spaceweather applications

Thank you for your attention!