Automated Geomagnetic Storm Detection at the Conrad Observatory

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In our world of growing dependence on technical and electronic infrastructure, a timely detection of geomagnetic storms and a prediction of their consequences on our daily lives is of ever increasing importance. An automated storm detector has been developed at the Conrad Observatory in order to detect incoming and arriving storms in real-time using a combination of solar wind data from the ACE satellite and data on geomagnetic variations from the Conrad Observatory.

Geomagnetic storms are caused by clouds of charged particles from solar coronal mass ejections (CME) reaching Earth and interacting with the magnetosphere. Consequences range from an interruption of satellite operations in near-Earth space (and therefore also temporary loss of GPS signal) to geomagnetically induced currents (GIC) at the surface endangering power grid operations. The severity of the effects we observe depends primarily on the strength of the geomagnetic storm, which is a result of many contributing factors in the solar wind, primarily the cloud intrinsic magnetic field.

The first step in our method of detecting storms deals with solar wind observations. The Advanced Composition Explorer (ACE, NASA/ESA) satellite lies on the L1 point, 1.5 million km from Earth on the Sun-Earth line, and it regularly sends back data on the solar wind with a 5-10 min delay. The time between a solar wind cloud arriving at ACE and arrival at Earth varies between 30 and 90 minutes and depends on the solar wind speed. This means we can have advance warning of an approaching cloud likely to cause a geomagnetic storm.

The signals that the detection algorithm searches for in the solar wind data are indicative of a CME shock front:

- sudden, discontinuous rise in solar wind speed
- rise in proton flux
- change in noise level after possible shock.

All of these parameters are evaluated and a “detection” of a change in these parameters is awarded a certain possibility of being a real CME shock. If a detection is made, a warning e-mail announcing a possible incoming storm is sent out to interested parties. This occurs ~20 minutes after measurement at the ACE satellite. Fig. 1 shows the solar wind data (ACE SWEPAM instrument) along with the geomagnetic data as an example of an arriving solar wind front. Note the earlier arrival of the CME shock front at the ACE satellite

The next step handles the geomagnetic data, which can be evaluated in near real-time in the observatory itself. The point of arrival of an effective CME shock into the interaction region with the magnetosphere is observable as an SSC at the surface. The time of SSC is picked out using wavelet analysis (Maximal Overlap Discrete Wavelet Transform) if the signal exceeds a certain threshold. This threshold is determined by studying past storms. If an SSC is detected, another warning e-mail can be sent announcing the definite beginning of a geomagnetic storm. This occurs within a few minutes of an SSC being measured.

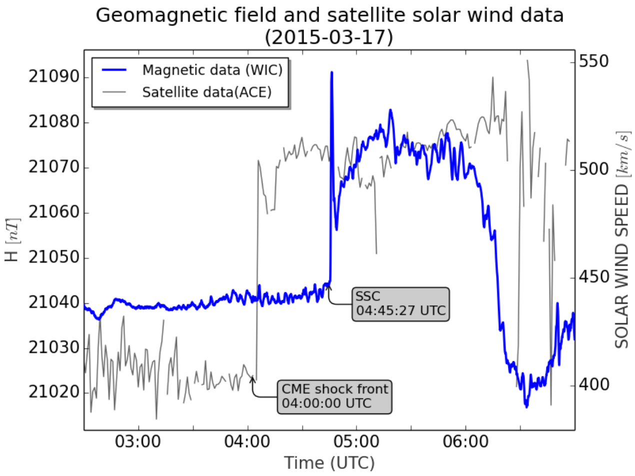

Figure 1: This plot shows (grey) the solar wind speed and (blue) the horizontal component of geomagnetic signal at the Conrad Observatory. The times displayed are the times automatically generated by the storm detection algorithm.

In Fig. 1, one can see the storm initiation times automatically generated by the detection algorithm for a geomagnetic storm on 17. March 2015. A detailed description of how the storm detector functions can be found in *Automated detection of geomagnetic storms with heightened risk of GIC,* Bailey and Leonhardt (2016, in review), Earth, Planets and Space.

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