The GOES-R Sudden Impulse Detection Algorithm

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Abstract:

Sudden Commencements can mark rapid changes in the Earth's magnetic field. Sudden Storm Commencements often precede Geomagnetic Storms, which produce currents that can impact a variety of terrestrial applications including the power grid (**Figure 1**) and oil pipelines. Accurate identification of these events in real time can provide the industries effected with the information needed to respond appropriately and mitigate these impacts.

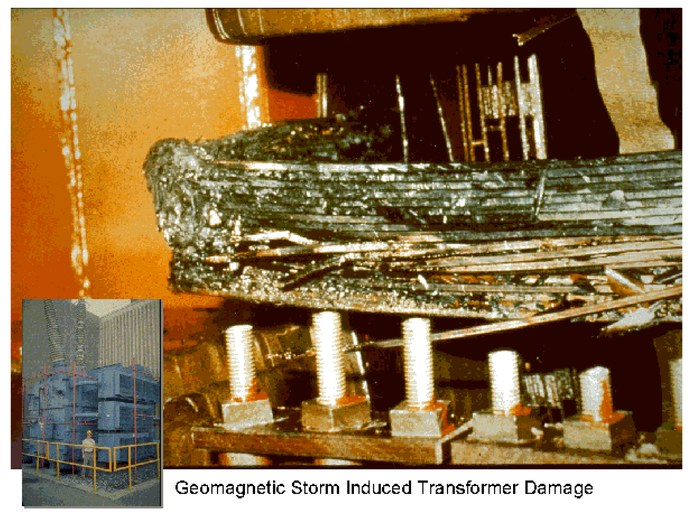

Fig. 1, damage to a transformer induced by a geomagnetic storm (http://www.swpc.noaa.gov/Media/graphics/Transformers.gif).

The Geostationary Operational Environmental Satellite (GOES)-R era Sudden Impulse Detection Algorithm will provide nowcasting capabilities for Geomagnetic Sudden Commencements. This will be accomplished by combining data from the magnetometers aboard the GOES satellites with data from multiple U.S. Geological Survey (USGS) ground-based sites at mid and low (but not equatorial)latitudes. Changes in these data will be used to form the basis for determination of whether an event is occurring.

Data from the ACE or DSCOVR satellites may be included to improve results, which might provide a short-term forecast component to the product. Incorporation of results from the Real-Time Disturbance Storm Time index provided by the USGS is being evaluated as a method to minimize repeated alarms during disturbed periods. Scoring has been performed by comparing events identified by the algorithm to the events identified by the International Association of Geomagnetism and Aeronomy (IAGA), as indicated in the Rapid Variations list maintained by the Observatory of Ebre.

Preprocessing:

Data are screened for quality ranging from calibration to nonphysical results. Different phenomenon must be screened out for the ground stations versus the GOES satellites, e.g. inconsistent measurements between the proton precession magnetometer and the vector fluxgate measurements for the ground magnetometers versus weekly calibrations on the GOES satellites.

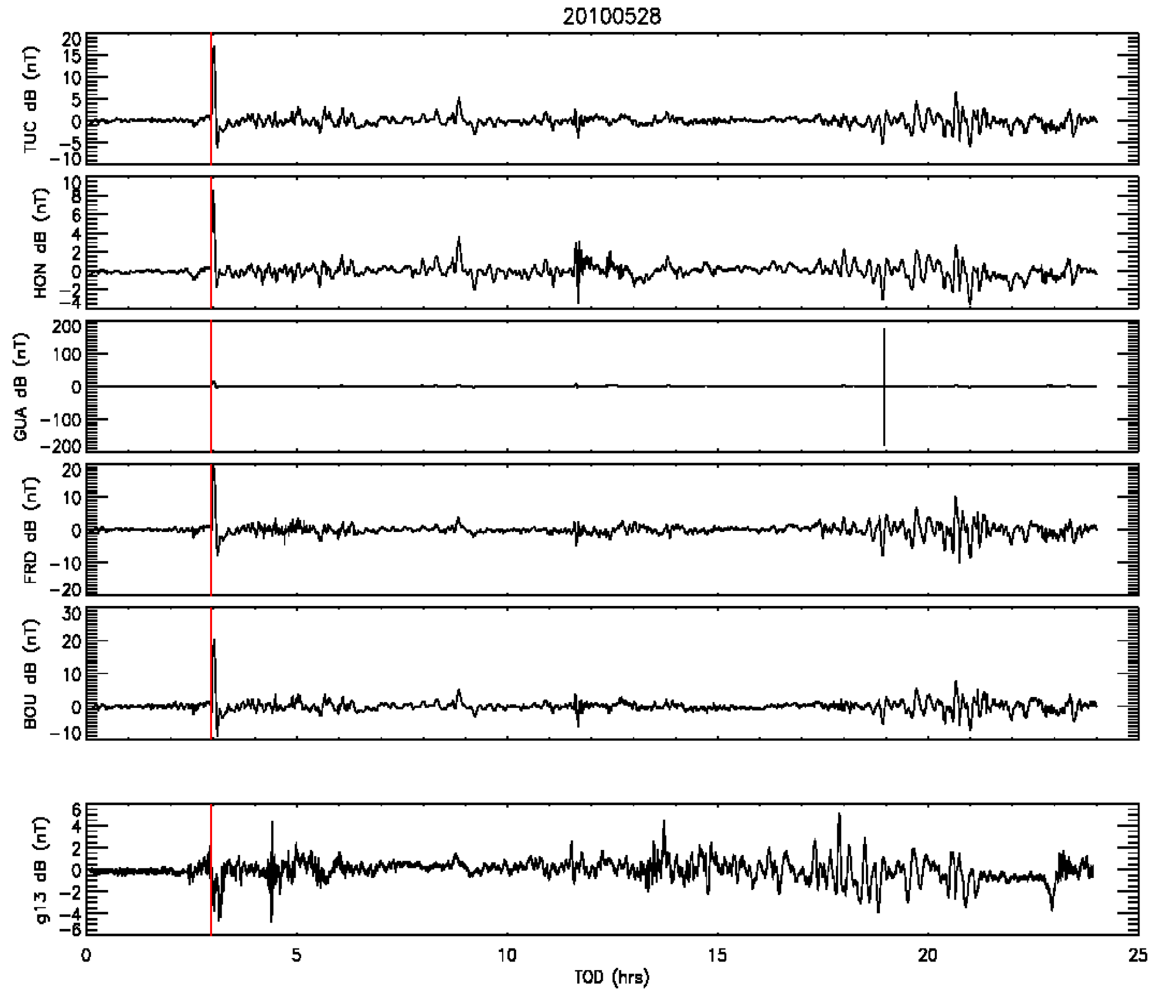

Fig 2, running difference between current measurement and the average of the past 300s for each ground-based observatory as a function of UT, 05/28/2010. This is used to determine the rate of change of the magnetic field experienced at each ground station, as well as GOES-13.

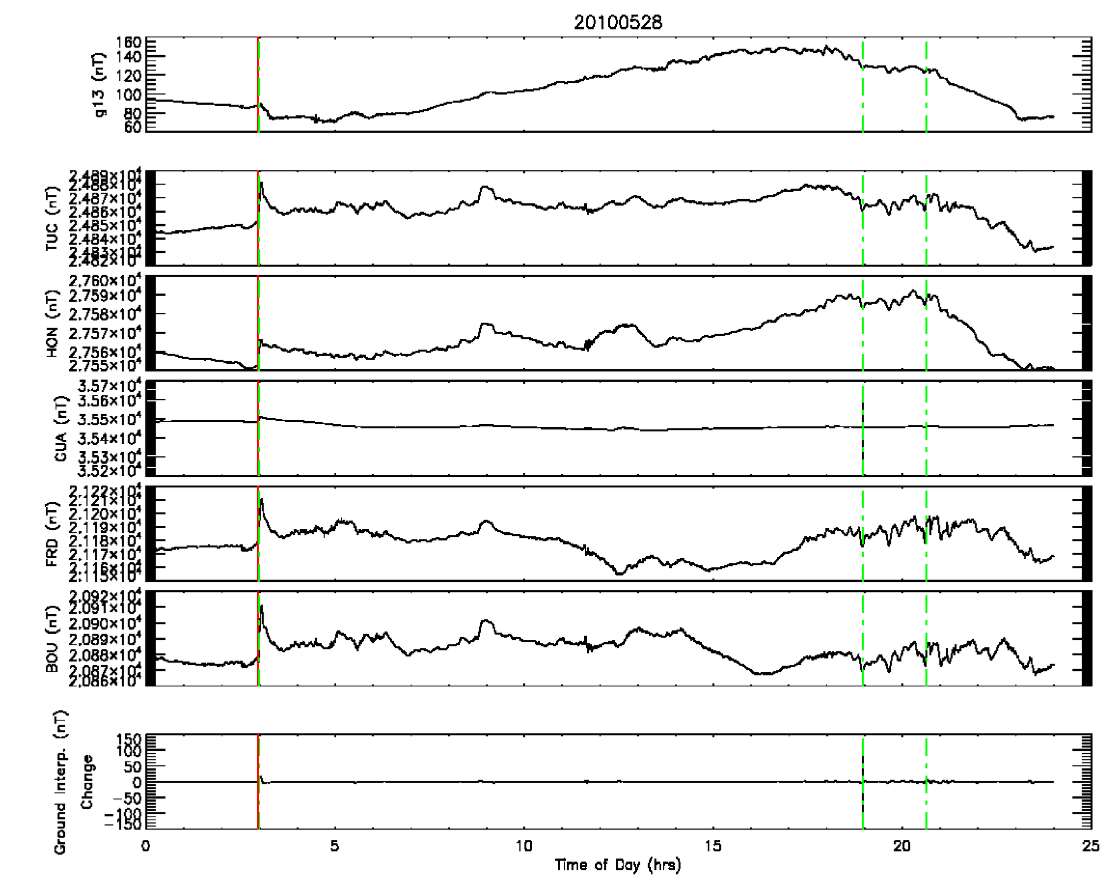

Fig. 3, raw data for each magnetometer station and the interpolated results using five USGS Ground Stations. Because SCs should represent a global phenomenon, it is not logical to make a determination based upon measurements at any single station. Because the stations available are not equally spaced, some form of interpolation as a function of geomagnetic longitude must be used. The results of this interpolation are seen in the plot marked "Ground Interpolated Change".

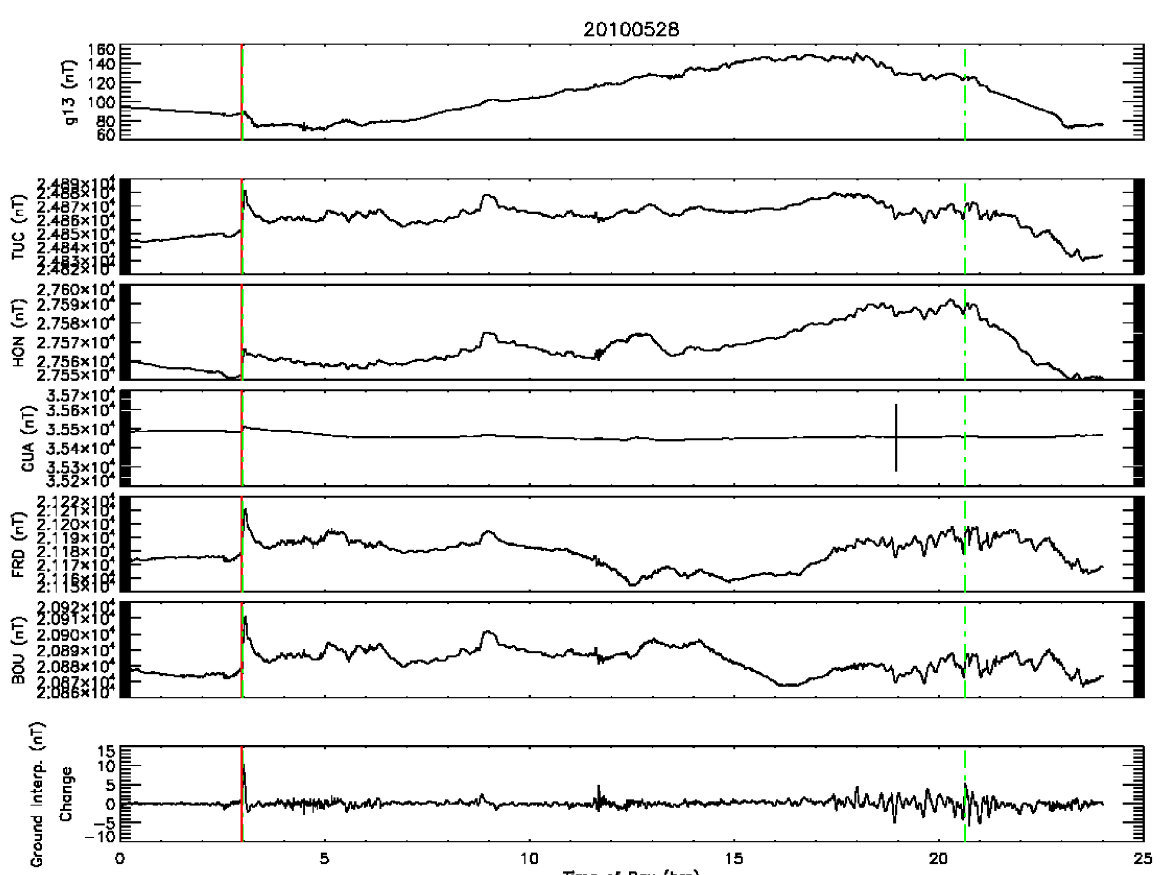

Fig. 4, raw data for each magnetometer station and the interpolated results from using USGS stations other than Guam. For a sampled global phenomenon, an SC should still be classified as an SC without the station experiencing the fastest change in the magnetic field. The current algorithm therefore requires that this criterion be met for any SC. In this case, this layer of screening eliminates a false alarm caused by a non-physical set of measurements at Guam at approximately 19:00 UT.

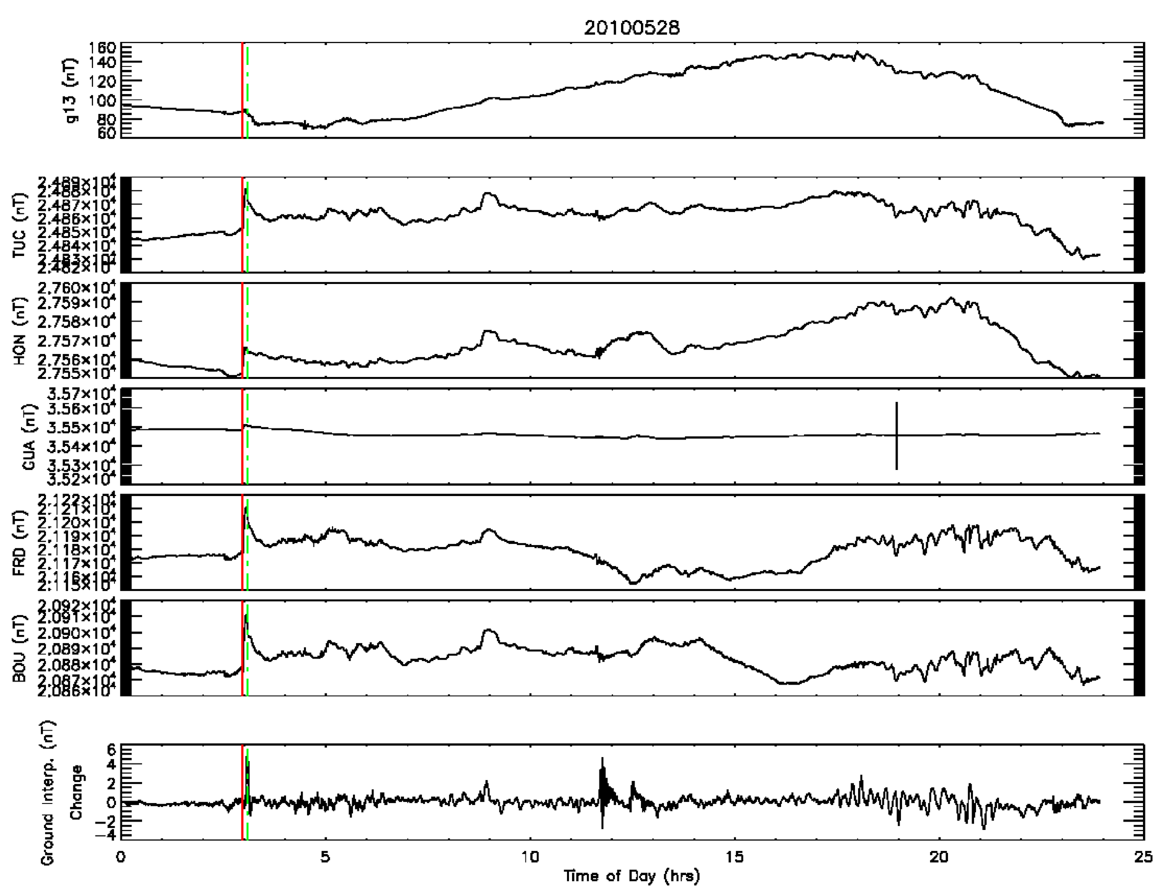

Fig. 5, interpolation is performed omitting Guam and including GOES 13. This is a variant on the technique used in the heritage algorithm, where two geostationary stations were combined with one ground station, and any time that two of the three showed conditions favorable for an SC an alarm was issued. (Joselyn '85) Only the IAGA standard SC is identified in this case. The technique used to include GOES 13 may be changed in a future revision.

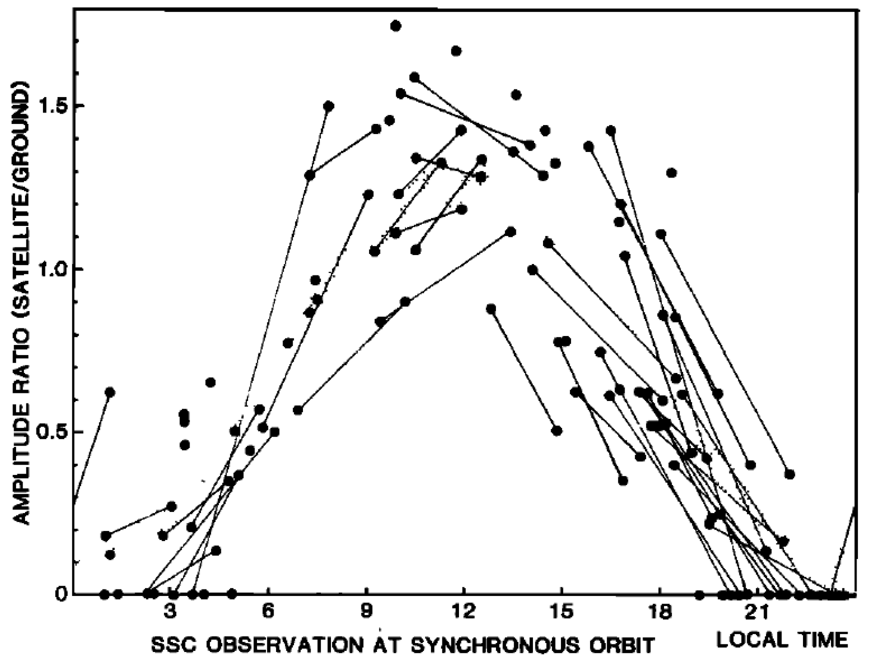

Fig. 6, "Local time distribution of amplitude ratios (satellite amplitude/ground) for 81 ssc events observed in 1978 and 1979." (Kokobun, '83). This demonstrates one of the potential difficulties in simply combining flags for the changes experienced at GEO satellites with those from ground stations, which was the technique utilized in the heritage algorithm (Joselyn '85). This is one reason that the technique used in **Figure 4** may be altered in the final algorithm.

Processing:

Figures 2 through 5 illustrate various stages of processing and the results. The red line, in each case, is the SC identified in the IAGA standard record. Green dotted lines show any times for which the algorithm would identify an SC at a given stage.

Figure 6 (from Kokobun '83) highlights some difficulties in combining GOES measurements with those of ground based magnetometers.

Conclusion:

Based one testing using three years' worth of data (2009-2011) the technique in use appears to be able to successfully meet a requirement of > 80% detection rate. Doing so while maintaining a false alarm rate of <10% poses an ongoing challenge.

The results of the algorithm being developed are a substantial improvement over the results for the heritage algorithm (Joselyn '85), which documented a 36% detection rate and a >100% false alarm rate using a single ground station and 2 GOES satellites as inputs.

Additional refinements to the interpolation technique being used and the method used to combine GEO and Ground station data may further improve the algorithm's results. The addition of ACE/DSCOVR data to the inputs is also under consideration if development time permits.

Acknowledgements:

The authors wish to thank Duff Stewert of the USGS for his timely efforts to make USGS ground station data available. They also wish to thank Josh E. Rigler (USGS) and Juan Rodriguez (NGDC/STP) for multiple helpful conversations. Multiple meetings with Space Weather Prediction Center (SWPC) staff have provided valuable insights into the customer's desires.

This work is being funded under the GOES-R Program Office's Risk Reduction efforts.

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