CrowdMag citizen-science apps for Space Weather detection

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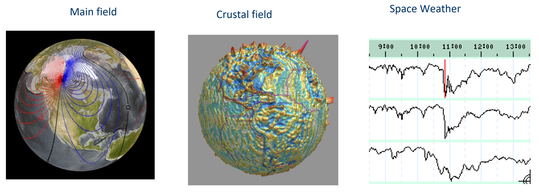
https://www.ngdc.noaa.gov/geomag/crowdmag.shtml

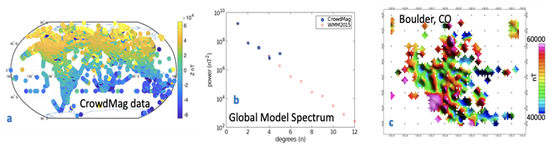
1. Earth's magnetic field

The magnetic field measured by a sensor near Earth's surface is the sum of magnetic field generated by a variety of sources. It includes the magnetic field originating from the Earth's core (about 95% of the total signal), magnetized rocks in the Earth's crust and the electric currents in the near-Earth space (Space Weather). Scientists use observatories, satellites and ship/airborne surveys to keep track of the change. The NCEI/CIRES geomagnetism group develops magnetic field models to aid navigation, resource exploration and scientific research. Due to gaps in coverage - both in time and space - scientists are always looking for alternative ways to obtain geomagnetic data.



2. Crowdsourcing magnetic data

All modern smartphones include 3-component magnetic sensors that are used to provide compass capability. The CrowdMag program developed and deployed smartphone apps that allow users to harvest data from their phones and deliver the data directly to NOAA for study. CrowdMag is the most downloaded NOAA mobile application (> 65,000 combined downloads for iOS and Android) is featured in the Department of Commerce Open Government Plan. The CrowdMag users have contributed more than 90 million vector data points from around the world .



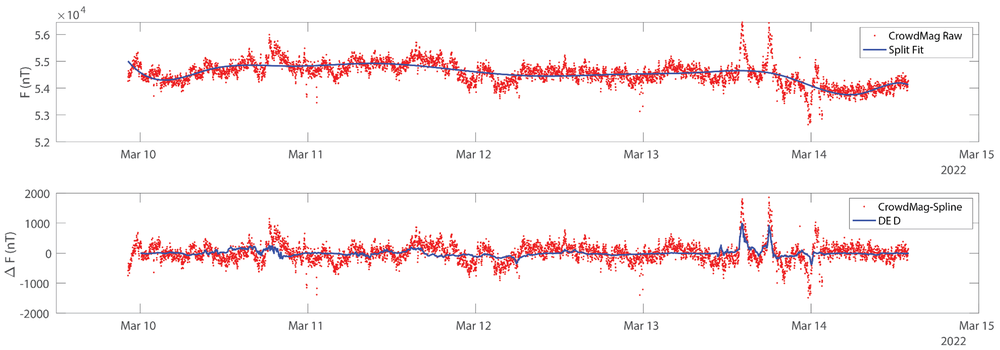
The CrowdMag data has been used to develop a model of the large-scale features of the Earth's internal magnetic field (a,b) and to develop the magnetic signatures of urban regions (c), where sufficient data were available.

3. MagVar app for space weather

Smartphone magnetometers were not created with the idea of tracking space weather. The phones employ Hall Effect analog sensors and typically have 16 bit analog to digital converters resulting in lowest bit resolution of, at best, ~150nT. In Boulder, for example, the largest peak to trough daily magnetic variation observed during our test period was only about 80nT. In Alaska, the daily magnetic variations are larger, frequently exceeding 200 nT or even 1000nT. We deployed a version of CrowdMag app (MagVar) on an iPhone 11 that averages magnetic data in 10-sec bins to reduce the random noise. This iPhone 11 was used to measure magnetic data at Deadhorse, Alaska for several days in January through March, 2022.

Deadhorse Geomagnetic Observatory (DED), Alaska

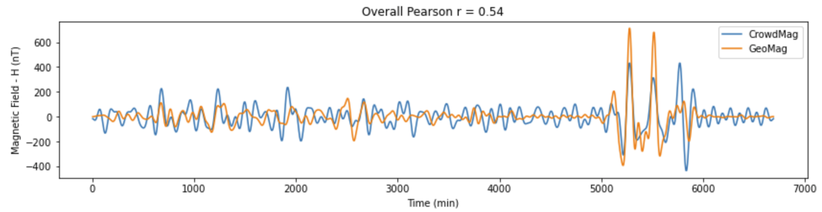
MagVar app recording at Deadhorse

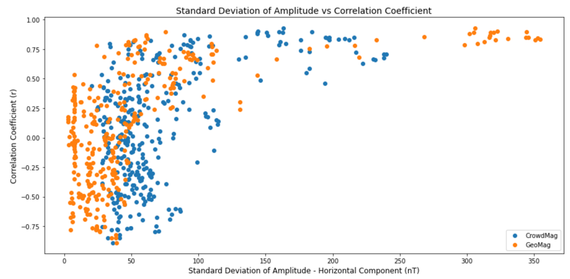


We find reasonable correlation between the Phone measurements and the data collected at USGS Deadhorse (DED) magnetic observatory in Alaska on days when the magnetic variations were strong (> 1000 nT).

4. Data processing

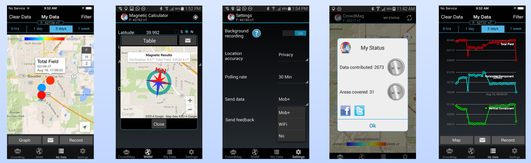
In order to further improve the correlation between the MagVar and Deadhorse observations, we developed a Python-based algorithm. In multiple steps, the algorithm applies a rolling average and a baseline shift on both datasets, and implements a bandpass filter and a butterworth filter to further smooth the signal. The following figure demonstrates the MagVar app and the Deadhorse Observatory measurements of the horizontal component of the magnetic field after signal processing, recorded on March 9 - 14, 2022.





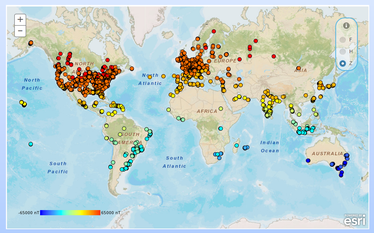
We calculated pearson correlation coefficient between the DED (GeoMag) and CrowdMag horizontal components on a 1-hour sliding window. In the above plot we compare the correlations with the standard deviations of magnetic fields. In general, we find that the correlation increases with increases in standard deviation - implying that the phone magnetometers are sensitive to space weather related magnetic field above a certain threshold.

CrowdMag Apps



CrowdMag apps are available at Google play store and Apple iTunes. In addition to measuring magnetic data, these phones also comes with a World Magnetic Model (WMM2020) calculator and a Compass.

Real-time data



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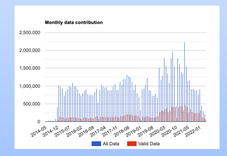
Facts

- 65,000+ users
- 2000+ unique devices
- 90+ Million data points



SUMMARY

- We developed a version of the CrowdMag "MagVar" to test whether the smartphones can detect space weather related signals.
- During our test measurements at Deadhorse, Alaska, the MagVar app detected several large peaks which are correlated with the data from the USGS Observatory at Deadhorse.
- Correlation between observatory and phone data increases during large magnetic fluctuations, implying that phone magnetic sensors can detect large space-weather related variations in the magnetic field.

Acknowledgements: CrowdMag app users for their data. Erik Bishop for data collection at Deadhorse, AK.