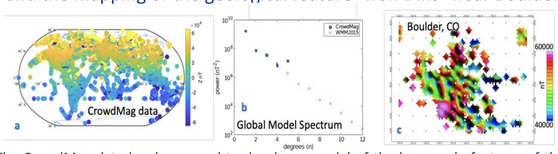
CrowdMag citizen-science project - 2023 Update!

Nir Boneh[1], Aamna Sirohey[2],Holly McCrory[3], Belinda Trotta[4], Rick Saltus[1], Manoj Nair[1] 1) Cooperative Institute for Research in Environmental Sciences, University of Colorado and NOAA's Centers for Environmental Information, 2) Sander Geophysics Ltd, Ottawa, Canada 3) University of Colorado, Boulder 4) Bureau of Meteorology, Melbourne, Australia

1. Annual overview

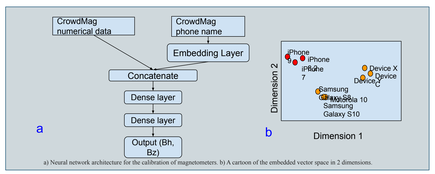
The CrowdMag program has developed smartphone apps that allow users to collect magnetic data from their phones and send it to NOAA for analysis. This program has been downloaded over 75,000 times and has accumulated over 100 million vector data points, thanks to contributions from users worldwide. Its goal is to involve the public in scientific research and improve our understanding of the Earth's magnetic field. Over the last year, the program has achieved several milestones. These include the successful release of the flight-mode version, the development of calibration algorithms based on machine learning, the creation of Python-based notebooks for processing data, and the mapping of the geological feature "Iron Dike" near Boulder, CO.



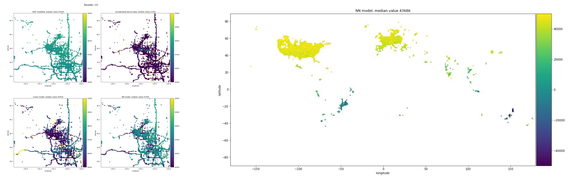
The CrowdMag data has been used to develop a model of the large-scale features of the Earth's internal magnetic field (a,b) and to develop the magnetic signatures of urban regions (c), where sufficient data were available.

2. Machine-Learning based calibration

We have developed a novel deep learning approach that links the anticipated geomagnetic field value (which is determined from high-quality data or models) with the measured CrowdMag data. This approach groups together devices with similar calibration characteristics in a multidimensional embedded vector space. The Figure below illustrates this method, where the left panel depicts the architecture for the deep learning system. As the errors from the loss function are backpropagated, the embedded layer will group phones with similar calibration characteristics in the vector space.



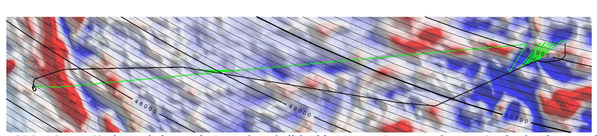
a) Neural network architecture for the calibration of magnetometers. b) A cartoon of the embedded vector space in 2 dimensions.



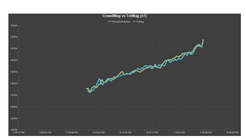
The figure on the left demonstrates the enhancement of the CrowdMag vertical component data using our ML calibration method as compared to linear calibration approaches, specifically in the Denver metro area. The same method is also applied to enhance the data collected worldwide, as illustrated in the figure on the right.

3. Flight-mode version released

On March 22, 2023, we released a significant update to the CrowdMag app that includes flight-mode capabilities. This update allows CrowdMag scientists to collect data while flying on commercial airlines, potentially filling in critical gaps in direct measurements of the Earth's geomagnetic field over remote areas, especially in the southern hemisphere. The app determines a "great circle" path for measurements based on the start and end airport locations, and uses GPS when available. Additionally, post-processing using actual flight paths downloaded from the FlightAware website can improve the accuracy of location estimation. A preliminary validation of the CrowdMag flight-mode data collected on a flight from San Jose, California to Denver, Colorado is shown in the figure below.



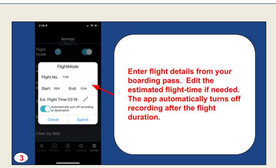
GPS + Great Circle path (green). Actual path (black). Magnetic anomaly map in the background

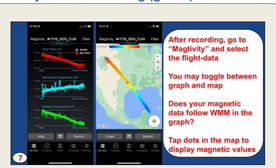


Adjusted CrowdMag (green) IGRF + Anomaly (blue)

Step-by-step instructions for flight-mode via NOAA tiny tutorial

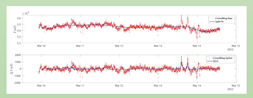
Easy to follow instruction set for flight-mode https://www.noaa.gov/education/resource-collections/data/tiny-tutorials/crowdmag-flight-mode



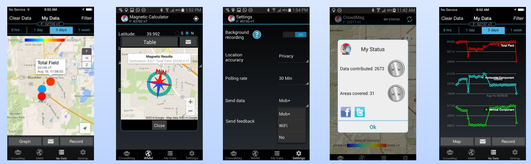


4. "MagVar" project for space-weather

We deployed a version of CrowdMag app (MagVar) that averages magnetic data in 10-sec bins to reduce the random noise. An iPhone 11 was used to measure magnetic data at Deadhorse, Alaska for several days in January through March, 2022. We find a 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). In order to explore this further, we were funded by CIRES IRP's proposal to develop a toolbox to allow the direct import of data files, produce initial quality plots, and perform basic anomaly processing. It will also provide tools for statistical comparison between magnetic observatory data and processed CrowdMagVar data and produce tables and plots of correlation analysis. The second task involves conducting high latitude outreach to study space weather-induced magnetic variations, targeted at advanced high school and early college educators and students in Fairbanks and Utqiagvik (Barrow), with special emphasis on outreach to non-traditional and Indigenous students.

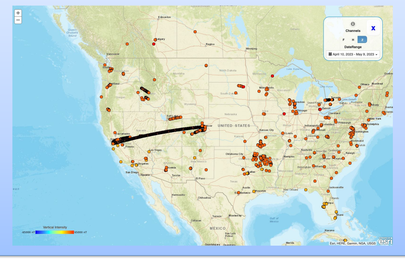


CrowdMag Apps



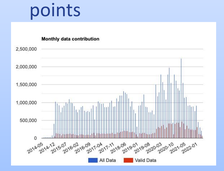
CrowdMag apps are available at Google play store and Apple iTunes. In addition to measuring magnetic data, these phones also comes with a World Magnetic Model (WMM2020) calculator and a Compass.

Real-time data



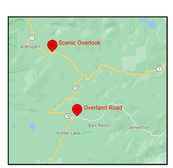
Facts

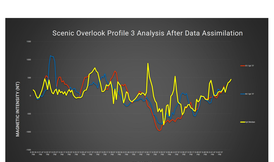
- 75,000+ users
- 2700+ unique devices
- 100+ Million data points

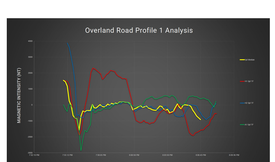


5. Magnetic mapping of "Iron Dike"

The Iron Dike is a wall of rock, almost 40 miles long, that extends through Colorado and Wyoming, containing magnetic minerals like magnetite (iron oxide). CrowdMag's ability to collect geomagnetic data has allowed the Iron Dike to be mapped accurately instead of having to rely on assumptions based on geologic principles. Holly McCrory, our RECCS intern, and her team tested CrowdMag at the Scenic Overlook near Allenspark and Overland Road near Jamestown, Colorado, and were able to locate the Iron Dike at the former by walking in step together perpendicular to where they knew it crossed underneath. They also found magnetic signals on top of the Iron Dike as they explored an abandoned mine located in the property adjacent to where they were taking data. The data sets were stacked and smoothed to help distinguish signals from the noisy outlying data points picked up by CrowdMag's sensors. The stacked profiles showed a steep rise and dip at the beginning of the Iron Dike, correlating with a magnet's positive and negative side, which is characteristic evidence of the Iron Dike.



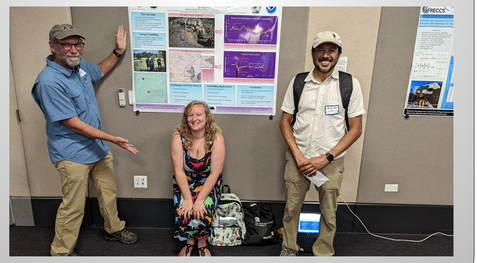




Location map (left). CrowdMag data across Iron Dike outcrop at Scenic Overlook and Overland pass

6. Presentations

National Association of Geoscience Teachers symposium.



Saltus, McCrory and Nair at The Research Experience for Community College Students (RECCS) poster session, July 2022

Acknowledgements: CrowdMag app users for sharing data.

https://www.ncei.noaa.gov/products/crowdmag-magnetic-data