Magnetometer Testing and Calibration

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Abstract

Understanding high altitude balloon rotation is important for many types of scientific measurements, therefore, balloon and payload rotation is a continuing area of interest and research. In this work, we present results obtained from an Arduino logged magnetometer rotated on a ground based rotation table. This table allowed us to precisely rotate and locate the Arduino logged magnetometer. We compare the Arduino logged results with "known magnetic field orientation" using an AIM rocketry altimeter. This comparison allowed us to test the accuracy of our Arduino logged results and the sampling capabilities of our magnetometer system using different rotational speeds.

Motivation

The calibration of the magnetometer helps us understand how balloon payloads rotate. When the solar eclipse occurs, relative orientation to the sun is important to data collection. The compass heading of the magnetometer gives us insight into the orientation and rotation of the payload. The orientation gives us the relative position of payloads with the sun.

Magnetic Field

1.

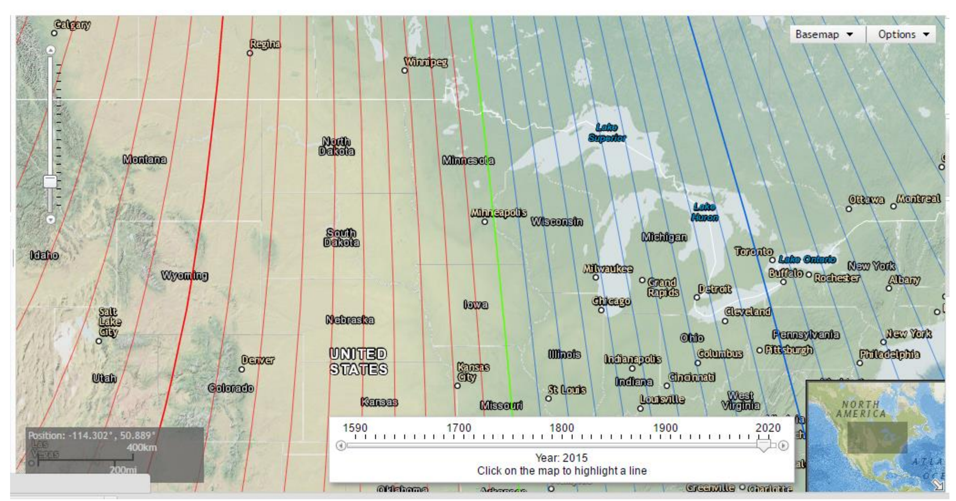


Figure 1. This map[1] shows lines of the same declination, which are called isogonic lines. Declination is the amount of error a compass, or magnetometer reads based on location. Right of the green line is a negative or west declination. Since the magnetic field of earth is slowly changing, the declination for a certain local can change over time. Declination should be calculated often[2] to ensure readings are accurate for use in magnetometer calibrations.

Rotation Table for Calibration

2.

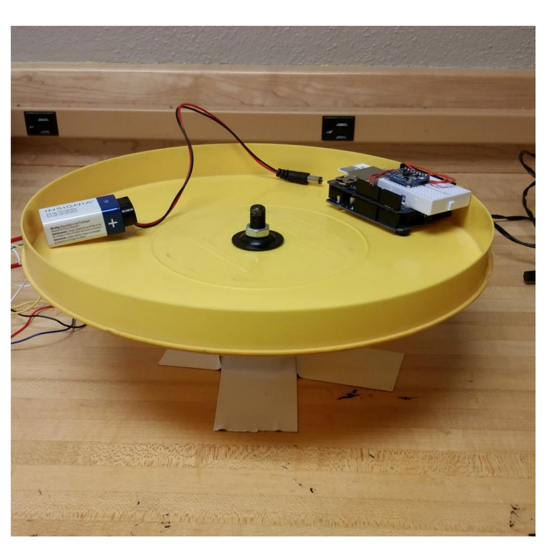
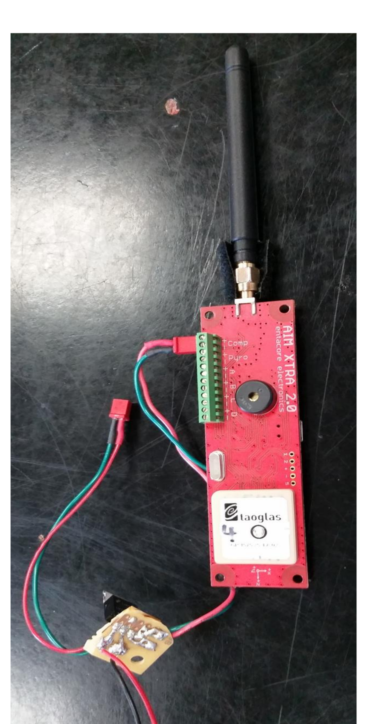


Figure 2.
The table is coupled to a unipolar stepper motor. The motor is powered through a 12 volt power supply. The stepper motor is controlled by an Arduino Uno. There are two rotation calibration programs: 1) the table goes to a certain angular position and remains at that local, 2) the table rotates continually at a set rate.

Magnetometers Tested

3a.



3b.

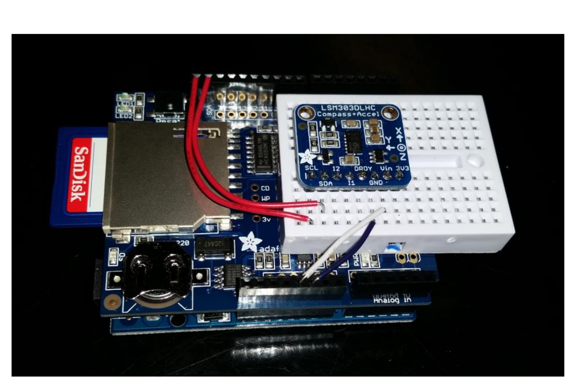


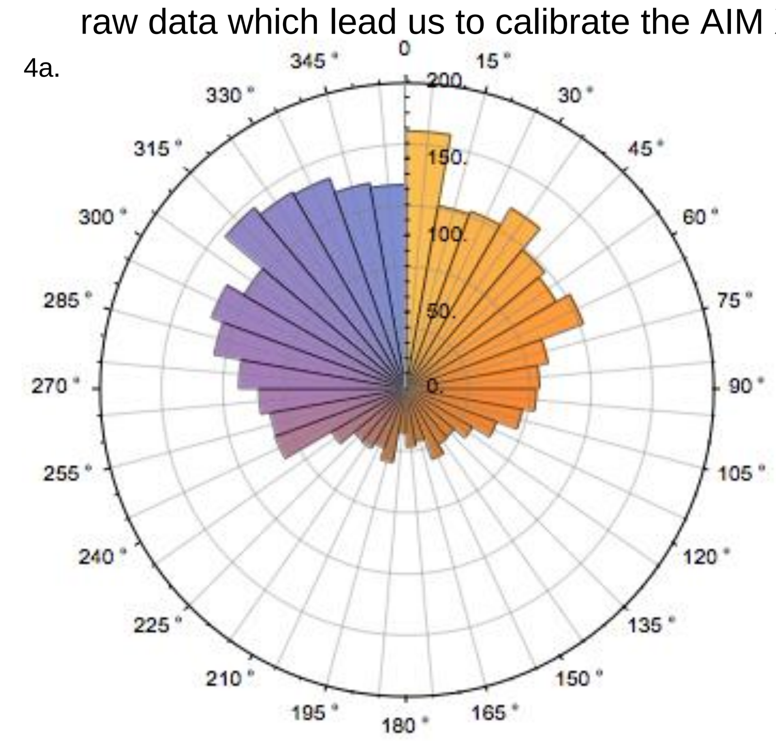
Figure 3a. The AIM XTRA is a sensor suite that includes a magnetometer, GPS, temperature sensor, accelerometer, gyroscope, altimeter, and pressure sensor.

Figure 3b. The Arduino magnetometer stack comprised of a SD shield, a real time clock (RTC) and magnetometer.

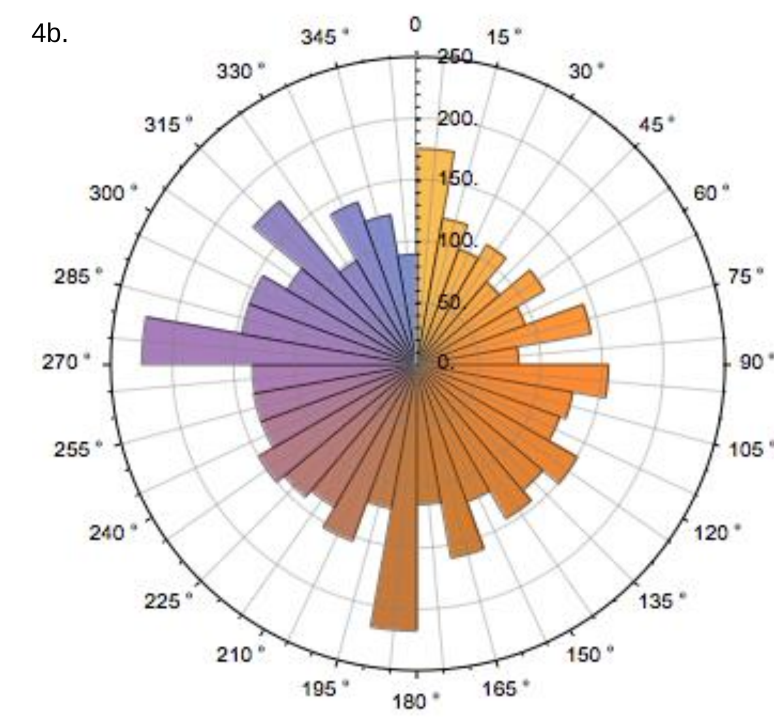
Calibration Data

Calibration was done by taking the three dimensional vector components of the magnetic field and finding an offset. The offsets were then subtracted from the values. To get an angular heading we took the arctangent of the x and y components. Earth's magnetic field has an inclination of 11 degrees. We have yet to take this into account in our calculations so the z component was not used. The circular histogram represents data as a compass. Zero degrees is North, 90 degrees East,180 degrees South and 270 degrees West. Our data is sorted into 36 bins each of 10°, the radial axis shows how many data points fall with in each bin. Figure 4c and 4d are representations of the same raw data which lead us to calibrate the AIM XTRA.

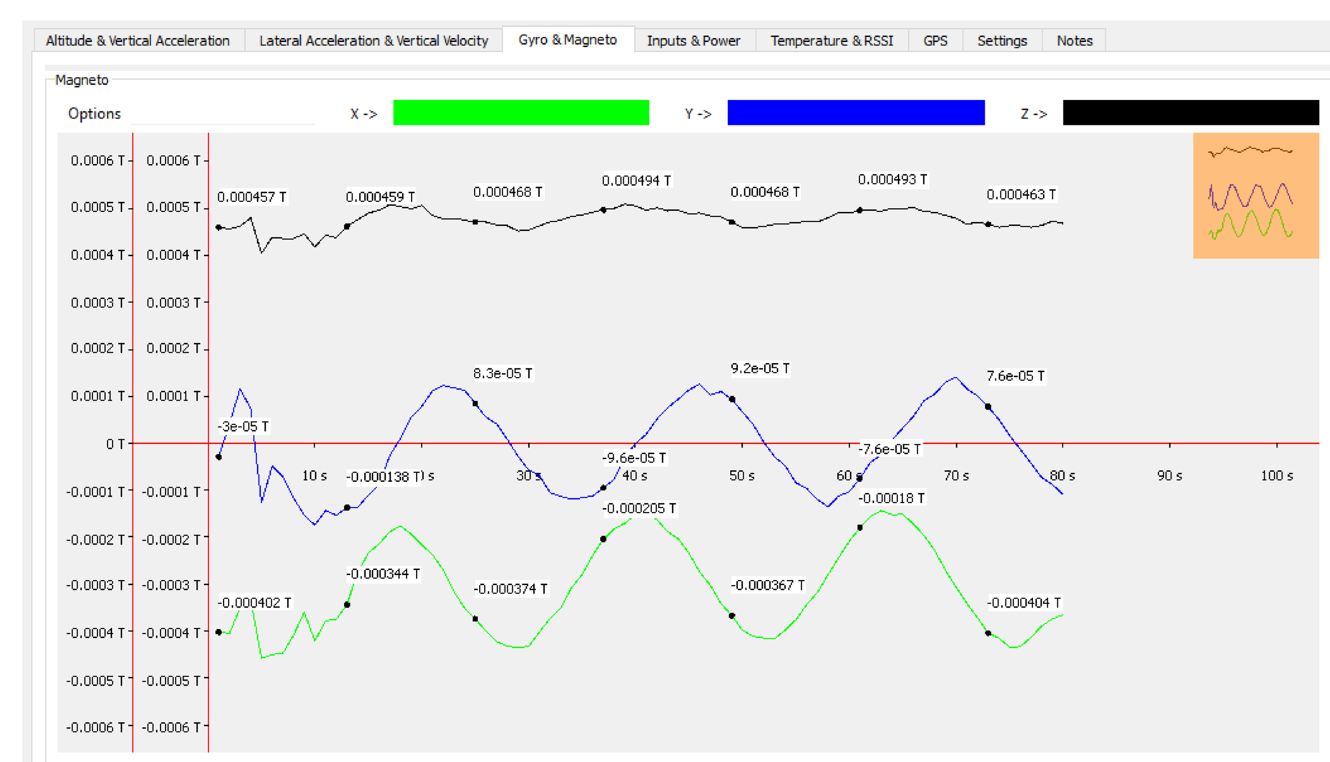
4a.



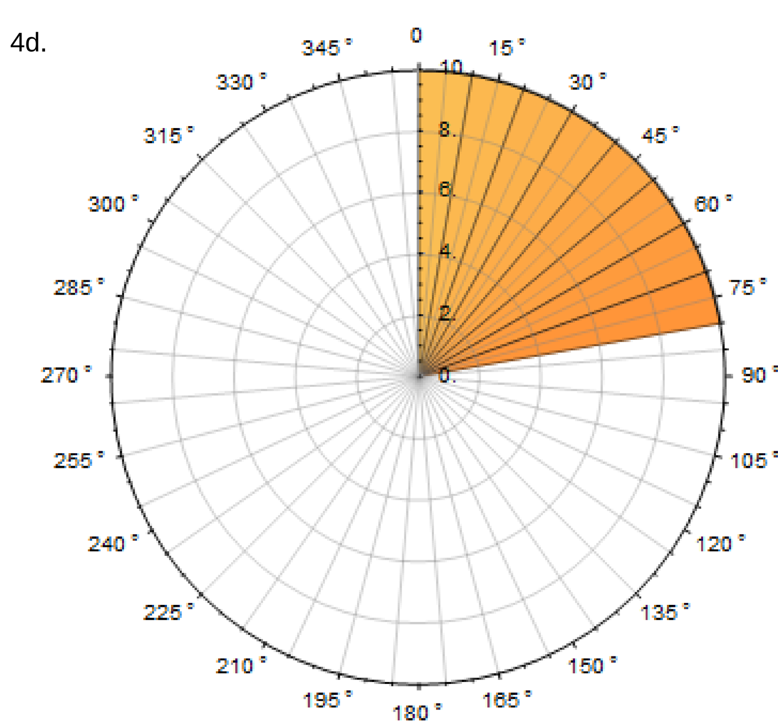
4b.



4c.



4d.



4e.

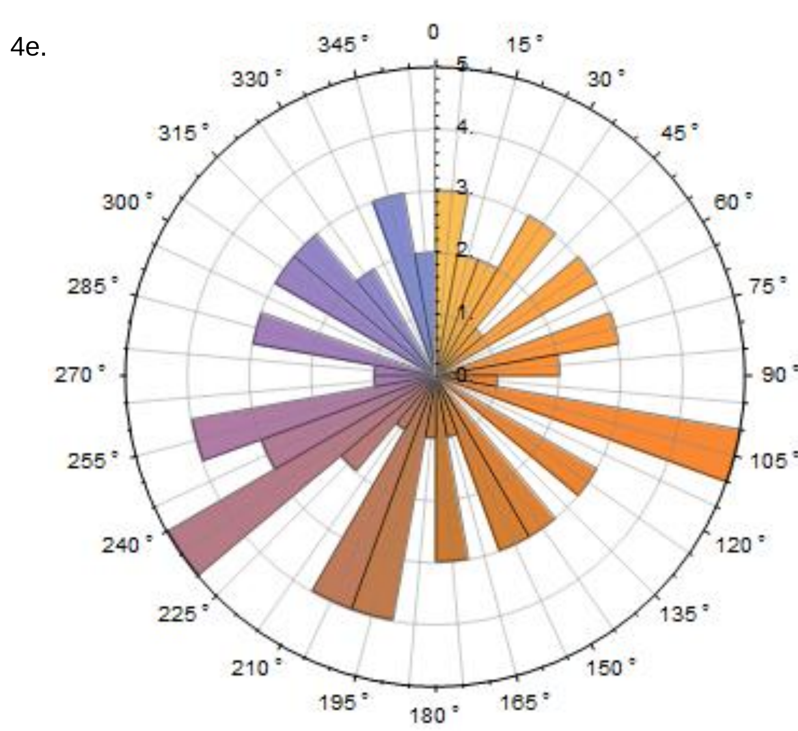


Figure 4a. Circular histogram of Arduino magnetometer continuously collecting run at .5 rev/s. Minimum bin count 29, max 168

Figure 4b. Circular histogram of 4a with calibration Minimum bin count 87, max 211

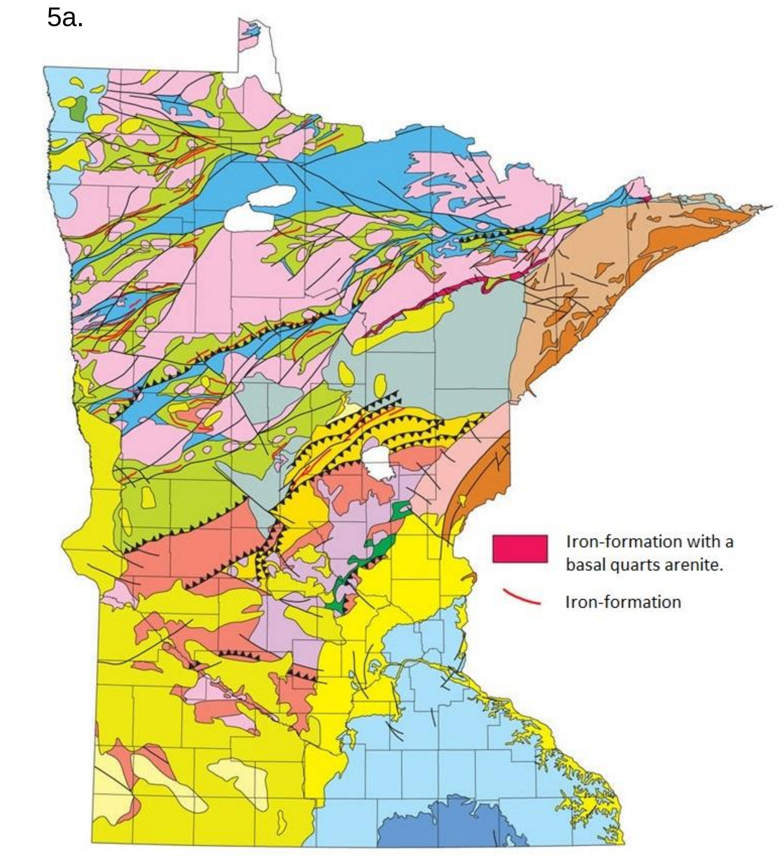
Figure 4c. Raw data of AIM XTRA magnetometer spun in a chair, collected at 100ms intervals. The x axis is time in seconds, the y axis is the magnetic field in Tesla. The z values in black ideally should be a flat line, because the magnetometer is not being moved vertically. The x values in green and y values in blue should have a 90° phase difference and both be centered over the x axis.

Figure 4d. Circular histogram representation of 4c. Minimum bin count 0, max 10

Figure 4e. Circular histogram representation of 4c with calibration. Minimum bin count 0, max 5

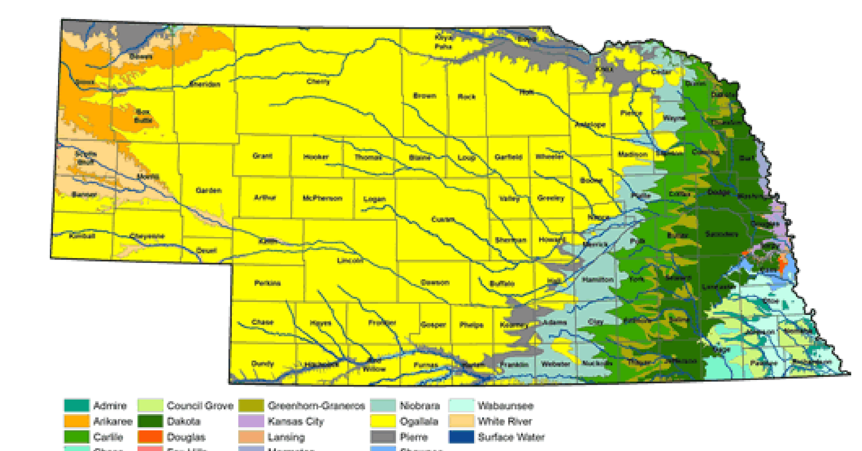
Possible Geological Effects

5a.



Magnetometers are very sensitive to slight variations in the magnetic field. The bedrock of Minnesota[3] is shown in figure 5a. There are a plethora of rock types including iron formations which can effect magnetometer readings. We are still in the preliminary stages, so we must take into account the ground effects. If those effects reach balloon altitudes is a question that we could explore with a flight in the Iron Range. However in figure 5b[4], which shows Nebraska, the bedrock has less intermingling rock types and no iron. To have the least effect on our magnetometer and to be similar to Nebraska we will fly in the Southern part of Minnesota.

5b.



Future Steps

A. We will continue to investigate the source of the deviation from the expected circular distribution of the calibration data.
B. To better determine the precision of the magnetometer we will decrease the step size in the calibration experiments.
C. We will explore additional magnetometers for accuracy, precision and ease of calibration.
D. We will run additional tests exploring the influence of external magnetic field sources (non-earth) while performing magnetometer calibrations. An example of preliminary experiment shown below.

6a.

6b.

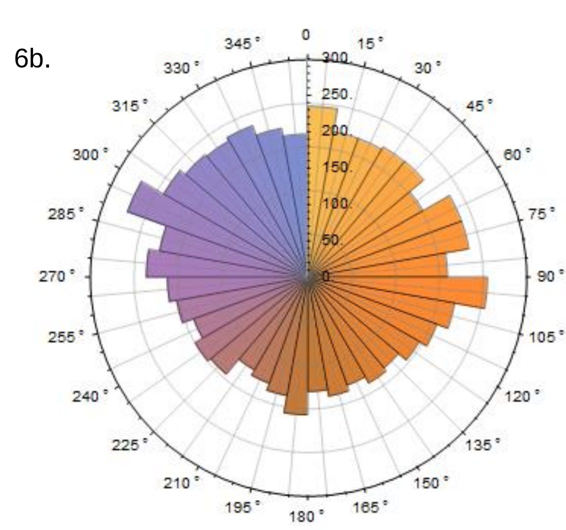


Figure 5a. Wooden spinning wheel in rural area. Colored tape suspends the Arduino on a single plane.

Figure 5b. Circular histogram collected from an Arduino logged magnetometer. The run was continuously collecting while attached to a wooden spinning wheel with calibration preformed. Minimum bin count 147, max 264

References

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4. Goeke, J., "What the Test Holes Told Us: From Drilling Data to Water Policy," *Prairie Fire: The Progressive Voice of the Great Plains* Available: http://www.prairiefirenewspaper.com/2014/09/what-the-test-holes-told-us-from-drilling-data-to-water-policy.

Acknowledgments

Funding support provided by:

NASA's Minnesota Space Grant Consortium (a higher education program)

Mathematics and Physics Department at St. Catherine University

St. Catherine University Carol Easley Denny Award- 2017 Solar Eclipse Preparations

St. Catherine University Academic Professional Development Committee Award