netPICOMAG: from design to networked implementation

Ian Schofield, Martin Connors: Athabasca University, 1 University Drive, Athabasca, Alberta, Canada, ian.schofield@athabascau.ca, martinc@athabascau.ca

Christopher Russell: IGPP UCLA, 405 Hilgard Ave, Los Angeles, CA 90095, ctrussel@igpp.ucla.edu

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ABSTRACT

netPICOmag (NPM) is the successful conclusion of Athabasca University's low cost magnetometer project, which aims to produce a laboratory-grade magnetometer (at minimum, detect 1 nT disturbances at a 1 Hz sampling rate) for roughly 500 dollars. Although we continue to make improvements, such as exploring new sensor types, we regard the design as mature and well tested. With careful calibration, netPICOmag units overlap with research-grade magnetometers. Without calibration, they can still sensitively detect magnetic variations and can be used for education or public outreach programs. Due to their low cost, such applications allow many students to be directly involved in gathering data, thus instill a sense of relevance when they witness auroras.

figure 1: NPM unit under test at Athabasca University Geophysical Observatory (AUGO), at Athabasca, Alberta.

PHYSICAL DESIGN

netPICOmag is a compact, self contained unit, purposely designed to be simple to install and operate. Consequently, its weatherproof 4-inch diameter, 36-inch long ABS tube contains all the magnetic sensors and electronics (GPS, DC-DC power conversion, network communication, microcontrollers). A single category-5E Ethernet cable configured as a Power-over-Ethernet (PoE) cable provides network connectivity and DC voltage, up to 100 meters away from a network access point.

Three orthogonally oriented Speake and Company FGM-3/3h pulse-count magnetic sensors are used to measure magnetic field perturbations as small as 1 nanotesla at a 1-Hz sampling rate, which minimally qualifies them as laboratory-grade instruments. The sensors emit a digital (5V DC) pulse stream whose frequency is near-linearly proportional to the magnitude of the magnetic field perturbations. Measurements are made in terms of the local geomagnetic field coordinates, X, Y and Z.

Frequency measurement is performed by twin Microchip PIC 18F252 microcontrollers. They count the number of elapsed digital pulses between successive 1-second pulses produced by the Garmin GPS engine (model 18 LVC). The pulse counters send frequency measurements to the NPM's main microcontroller, a Rabbit Semiconductor RCM4010 core module. It accumulates 10 seconds worth of time-stamped data (the time is also read from the GPS's NMEA-0183 telemetry stream) and transmits the packet in a UDP datagram. There is no provision for retransmission of the packet if it is lost.

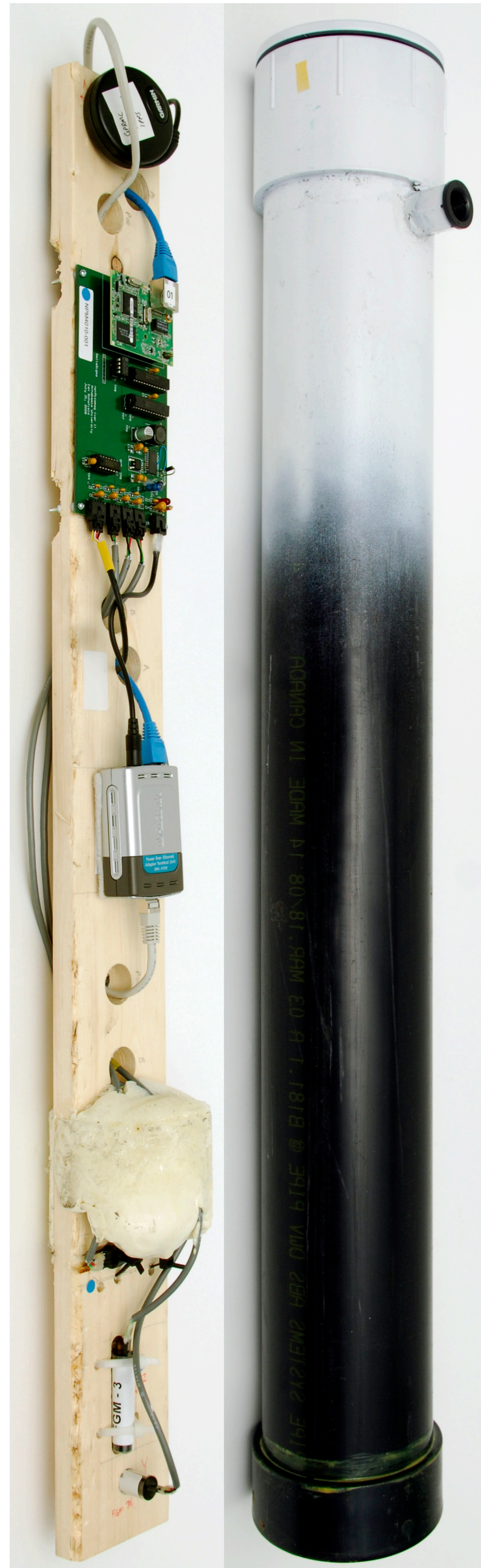

figure 2: NPM unit; interior, exterior. photo by Blaise MacMullin

OPERATION

The goal of the NPM project is to demonstrate dissemination and operation of a spatially-dense magnetometer network involving numerous low-cost units. In order to keep costs to a minimum, NPM was designed to allow individuals without experience in ground-based magnetometry to install the units themselves. The plan is to send units directly to interested organizations (schools, colleges) or individual enthusiasts (amateur astronomers) by mail or courier. Upon receipt of the instrument, the operator will install the NPM by boring a ~2.5-foot 6-inch diameter hole in the ground, place the NPM in the ground, align the unit to magnetic north (easily found with a compass) and trench the power/network cable to their building or home. Provided there exists continuous network connectivity, the NPM will automatically determine its network address (using DHCP) upon power-up and begin sending data packets over the Internet every 10 seconds.

Data is sent to our primary data repository at Athabasca University, where it is archived and plots are generated on an hourly basis. Operators, students and enthusiasts can inspect data coming in from the network at the NPM public data portal, http://autumn.athabascau.ca. Plans are underway to create a separate website dedicated to the NPM project that provides educational resources and real-time data plots. The site should be online by September 2009, in time for the new school year.

PERFORMANCE

The NPMs deployed at the Athabasca University Geophysical Observatory, in Athabasca, Alberta, and at a private residence at Legal, Alberta, successfully demonstrated that NPMs could run reliably for long durations (continuously over 12 months). The only difficulty experienced was the potential for flooding during spring thaw. The NPM housing (and cable feedthrough connector), although water resistant, is not waterproof, and will leak if submerged. It will be recommend that operators install NPM units in areas where water will not accumulate, such as on hillsides or high-lying areas. Heavy snow-cover over a NPM installation is beneficial during winter months as it provides an ideal thermal blanket, moderating thermal variations that bias the data coming from the FGM-3 sensors.

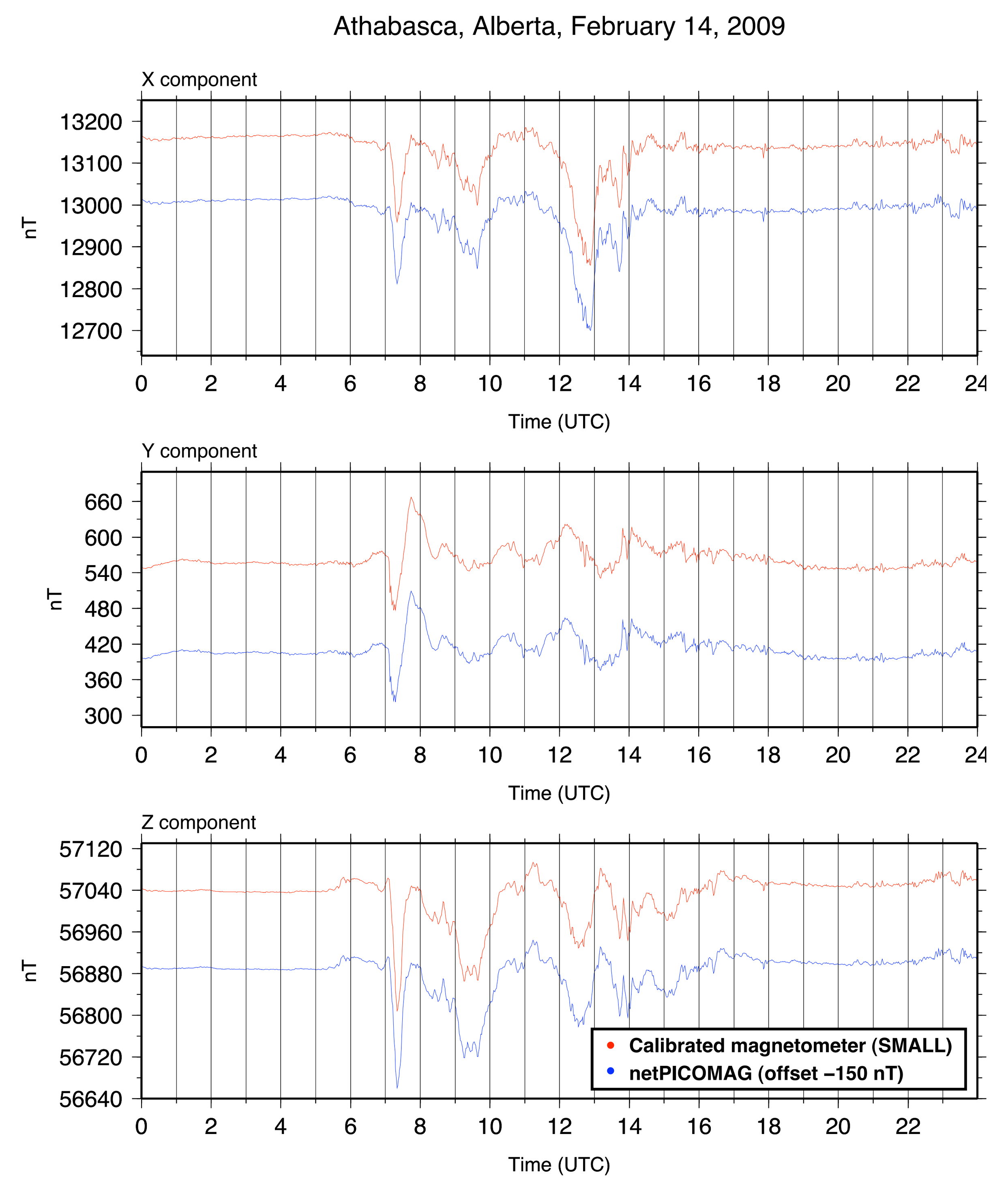

figure 3: Magnetic activity at Athabasca, Alberta on February 14, 2009. Data from a calibrated UCLA-SMALL fluxgate magnetometer (in red). NPM magnetic data (in blue) is offset by -150 nT.

Figure 3 shows vigorous magnetic activity that occurred on February 14, 2009. The three time series show the respective magnetic field components (local magnetic X,Y,Z) as measured by an NPM magnetometer (shown in blue), and a calibrated, 10 pT resolution UCLA-built SMALL fluxgate magnetometer (shown in red). The NPM data has been offset from the SMALL data by -150 nT in order to distinctly show the data from both magnetometers.

Magnetic field strength measured in the X component shows a strong negative spike at local midnight (7 UT), pointing to intensification of westward ionospheric currents (electrojet). A strong, 300 nT bay in the Z component points to the substorm occurring north of the observation site (Athabasca). The westward electrojet intensifies even more at 5 AM local time (13 UT). The relatively weaker perturbations in the Z component at this time suggest the magnetic disturbances have moved southward.

Figure 4 shows the residual from both instruments. The residual is greatest when perturbations are most intense, and is due to small scale misalignments of the NPM's magnetic sensors. The NPM data has only been scaled and offsetted; no thermal biasing curve has been fitted and subtracted out of the data.

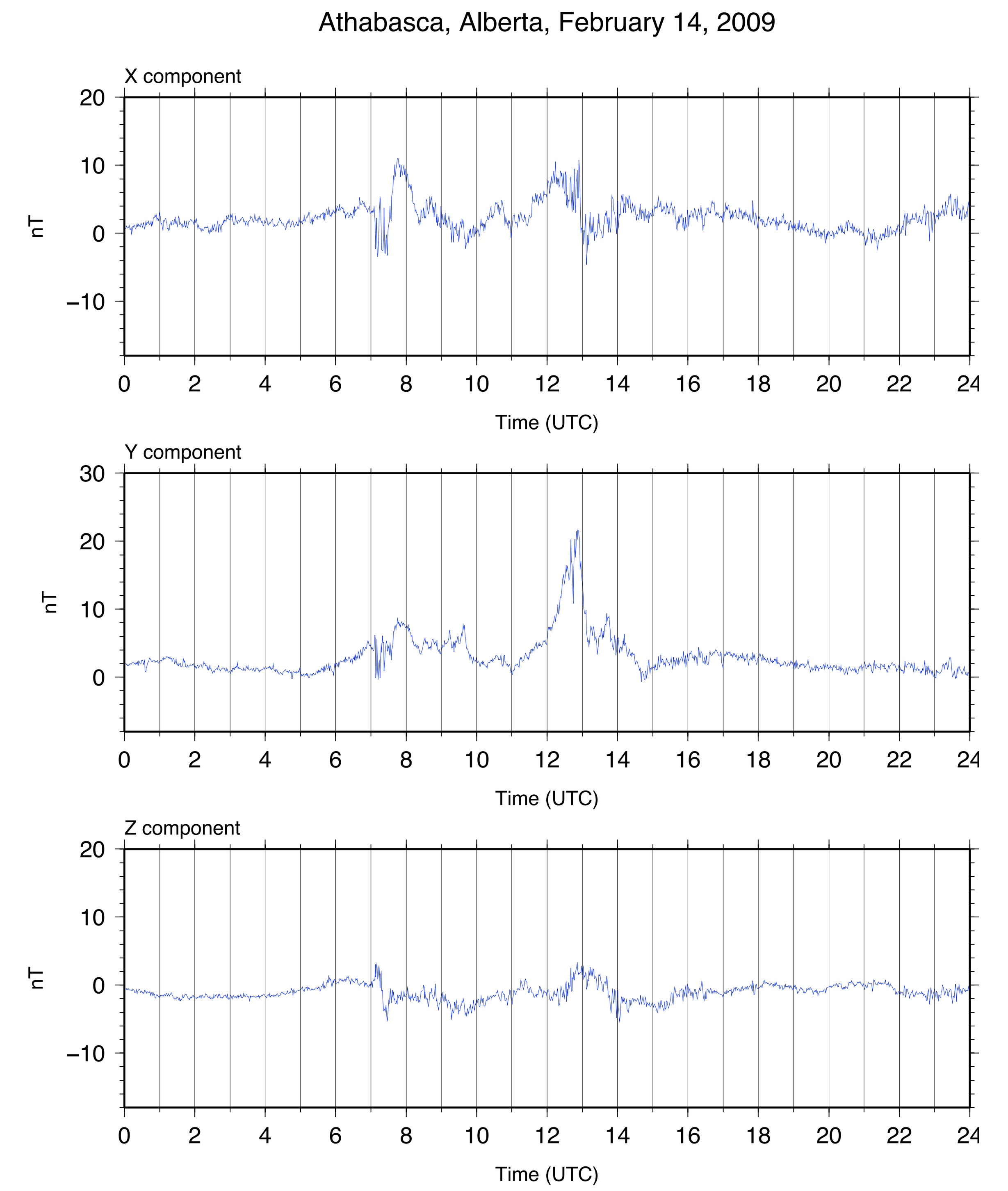

figure 4: Residual plots from SMALL and NPM data.

APPLICATIONS

NPM was first envisaged as a teaching tool to demonstrate the relationship between fluctuations in the Earth's magnetic field and the appearance of the aurora. In this application, NPM can be considered to be an "Aurora Detector". Development of spatially dense magnetometer networks for science or industry can benefit from NPM's exceptional price to performance ratio if they are deployed at auroral latitudes where Bx and Bz field components are strong enough to be adequately measured by NPM's relatively low magnetic sensitivity (1 nT).

ACKNOWLEDGMENTS

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