Cosmic ray muon flux measurements correlated to atmospheric pressure fluctuations and solar flare activity

David Buitrago, Prof. Raul Armendariz, Prof. Chantale Damas

Department of Physics, Queensborough Community College of the City University of New York

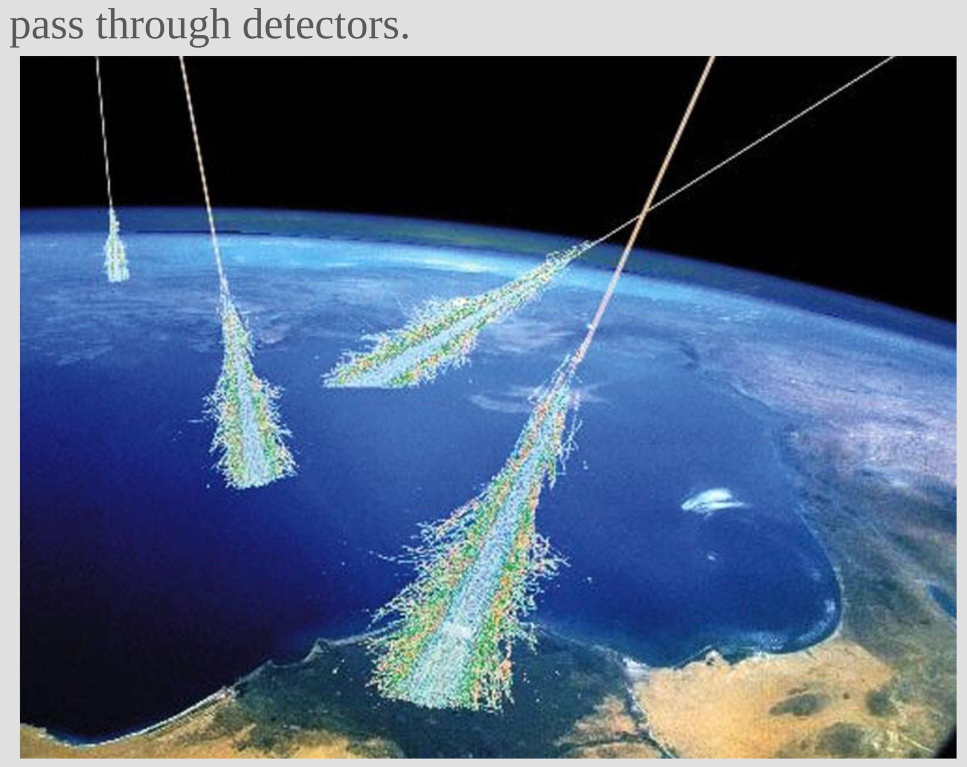
Community College Undergraduate Research Initiative, CCURI Conference, Austin Community College, Austin, Texas, November 30, 2017

Abstract

When an incoming cosmic ray proton or atom from outer space collides with particles in earth's atmosphere a shower of secondary muon particles is created. Cosmic ray muon flux was measured at the Queensborough Community College using a QuarkNet detector consisting of three stacked polyvinyltoluene scintillator counters, photomultiplier tubes, and a two-fold coincidence logic trigger. A computer program was created in Python to calculate the muon flux rate and atmospheric pressure sensor readings from the detector's data acquisition board. The program converts the data from hexadecimal to decimal, re-bins it in a more suitable format and creates plots of muon flux versus atmospheric pressure. Cosmic ray flux was measured over March 13-17, 2017 during an extra-tropical cyclone (winter storm *Stella*, NESIS category 3), and is shown to be inversely correlated with atmospheric pressure. Cosmic rays were measured over September 6-11, 2017 during a period of heightened solar activity including an X9.3 solar flare; several drops in muon flux were recorded and compared to increased proton and x-ray flux measurements made by GOES space weather satellites.

Introduction

When incoming particles (protons, electrons, and atoms) from outside of Earth's atmosphere collide with atmospheric particles they create secondary particles that reach Earth's surface. Cosmic ray detectors have been built in QCC as part of a collaborative effort with QuarkNet to detect these incoming particle showers and measure their characteristics as as they pass through detectors.



One of these characteristics is flux, which is a measure of how many particles pass through the detector per m^2 per minute:

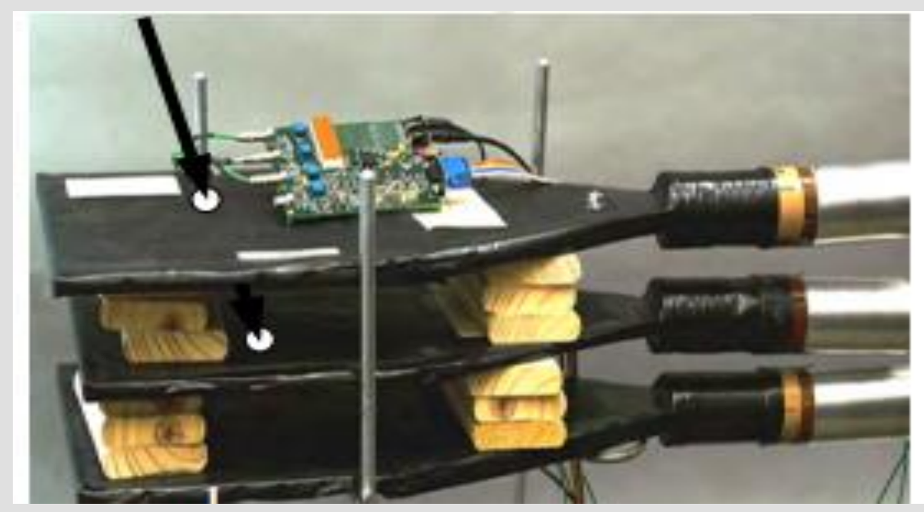
$$\varphi = \frac{\frac{\#event}{seconds} * 60sec/min}{area\ of\ counter\ cm^2 * \frac{1m^2}{10{,}000\ cm^2}} = counts/min*m^2$$

Flux varies frequently for different reasons one of which is atmospheric pressure.

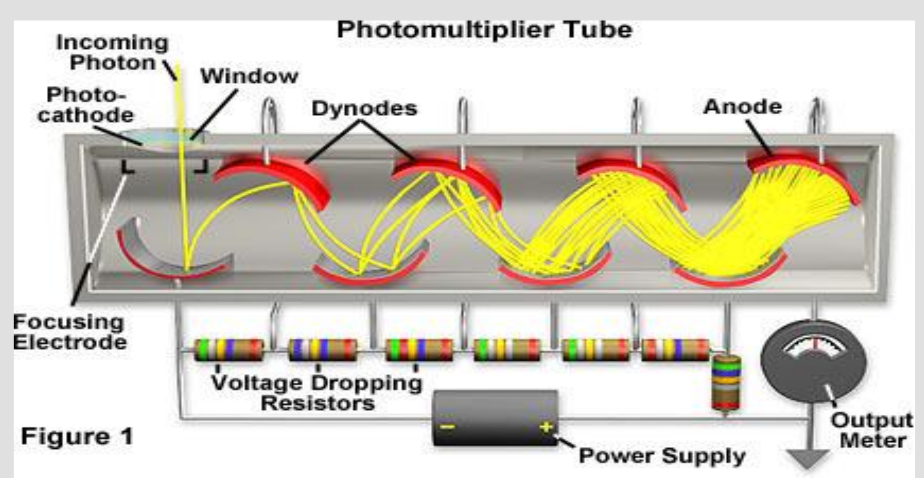
Materials & Methods

Methods

To detect incoming muons, counters such as these are set up and wired to a DAQ board that takes timing information and determines the validity of a pulse signal.

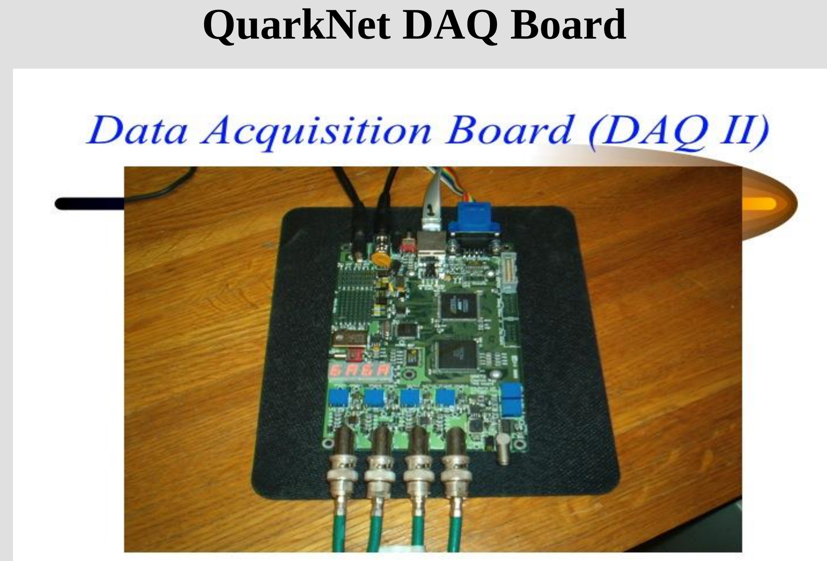


The counters are made of polyvinyltoluen scintillator, a special fluorescent plastic which converts charged particle kinetic energy into faint light flashes; and photomultiplier tubes (PMTs) that collect these trace amounts of light, converts them into amplified pulses of electrical charge as detectable signals.



Because PMTs create noise they are plateaued to find their ideal voltages. The DAQ board is programmed with AND gate coincidence logic requiring two pulses from different pmts occur within tens of nanoseconds of each other; this ensures particles are seen by both detectors near simultaneously and most likely to be cosmic ray muons.

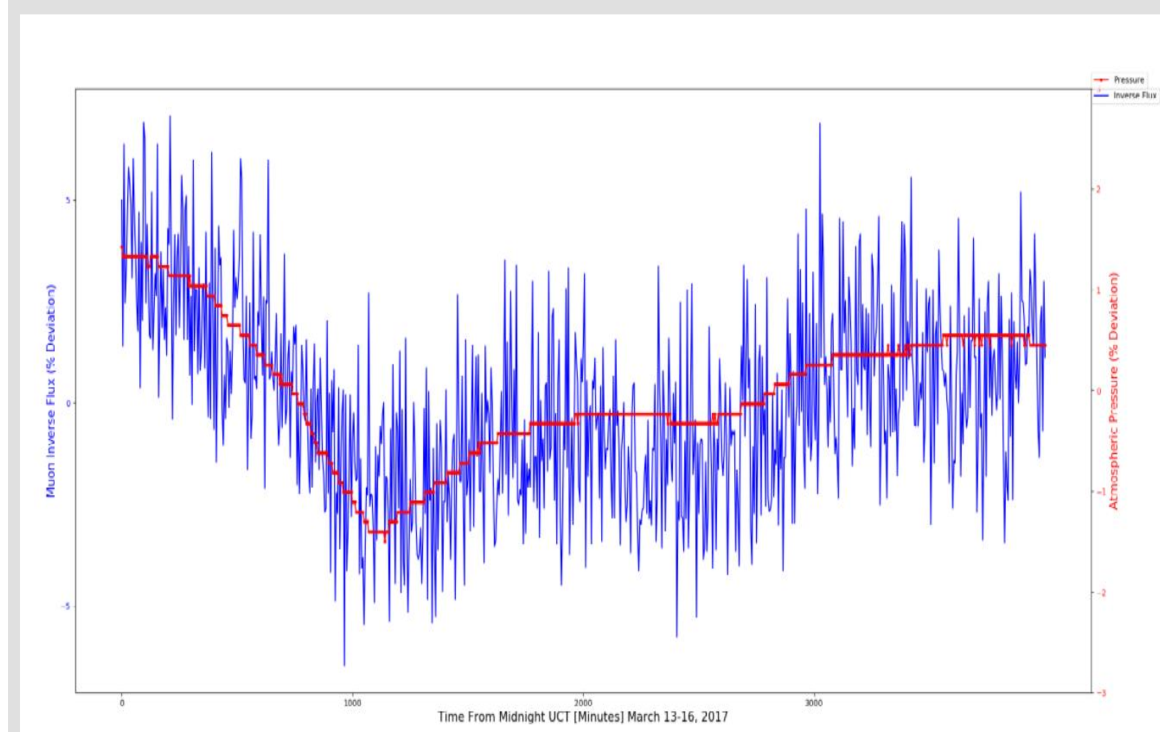
QuarkNet DAQ Board



The DAQ boards use a GPS antenna and receiver to check for a valid number of satellites and GPS time (UTC) for each particle detected; it has onboard logic measuring pulse relative timing information within 1.25 ns; and includes a barometer to measure atmospheric pressure.

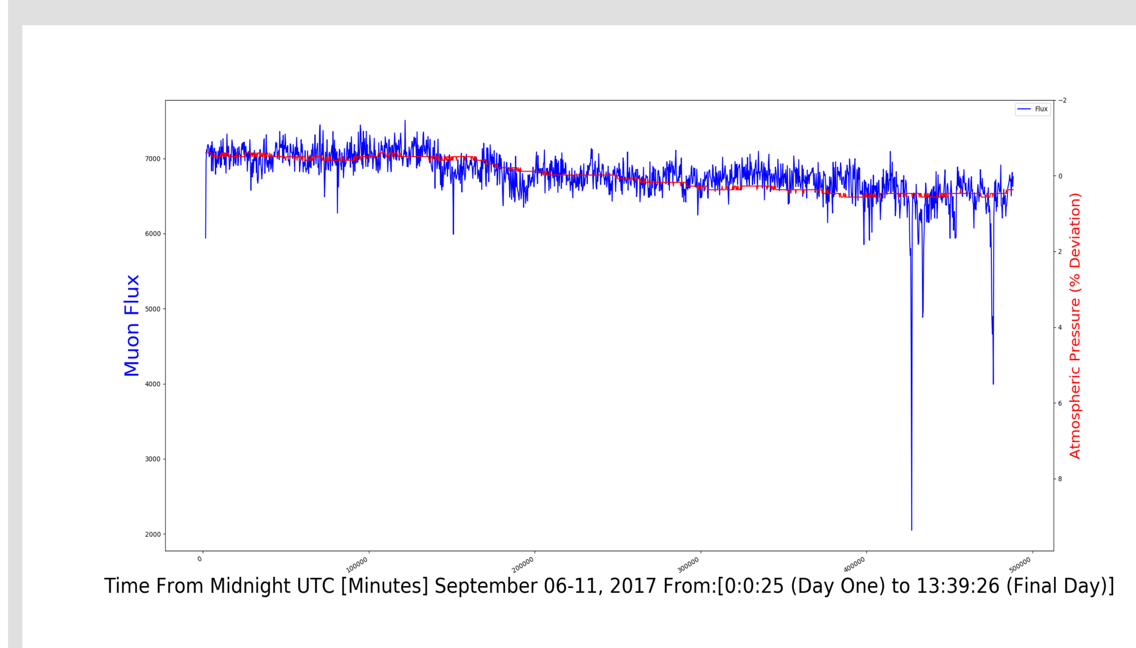
Results

Our data is in the QuarkNet standard ASCII-2 format. A Python program was created to read in the raw data and graph changes in flux and pressure. First we demonstrated our Python program created the same flux plot that QuarkNet elab creates; then we added various features to our plotting code. The plot below is flux and pressure measured at QCC during winter snow storm *Stella* in New York City over March 13-16, 2017.



The above graph shows a strong anti-correlation in pressure (red) versus flux (blue), the reciprocal of flux is plotted: a 2-3% change in pressure correlates to a 5-6% change in flux. This occurred during a snow storm where the pressure decreased drastically.

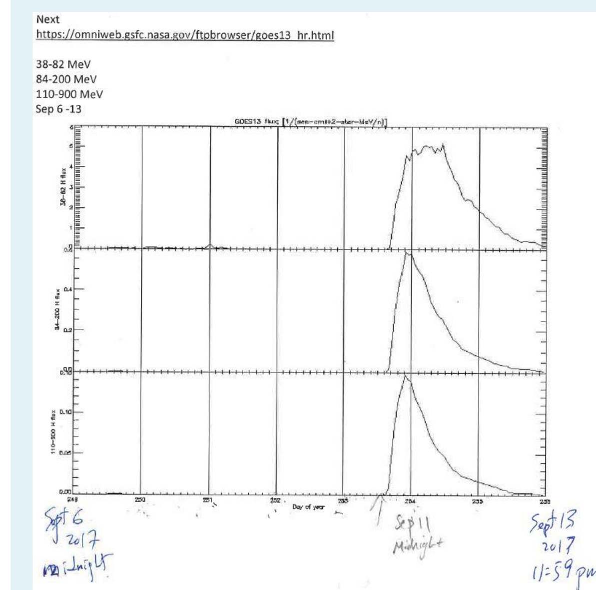
Another rare event occurred this year: several large solar flares in September including the biggest recorded in the past seven years. Muon flux was measured with our QuarkNet detector over this period as shown below.

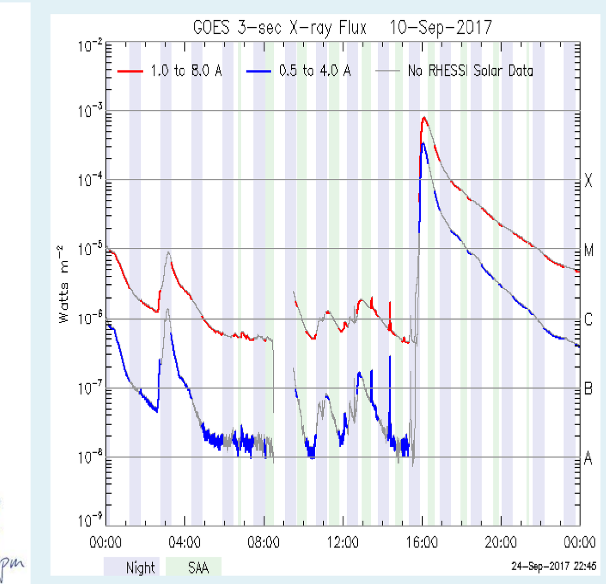


The above plot shows a steady decrease in muon flux (blue) follows the inverse atmospheric pressure (red). Over multiple days large solar flares occurred and large drops in flux were recorded on those days, with the largest one being towards the end of our data run.

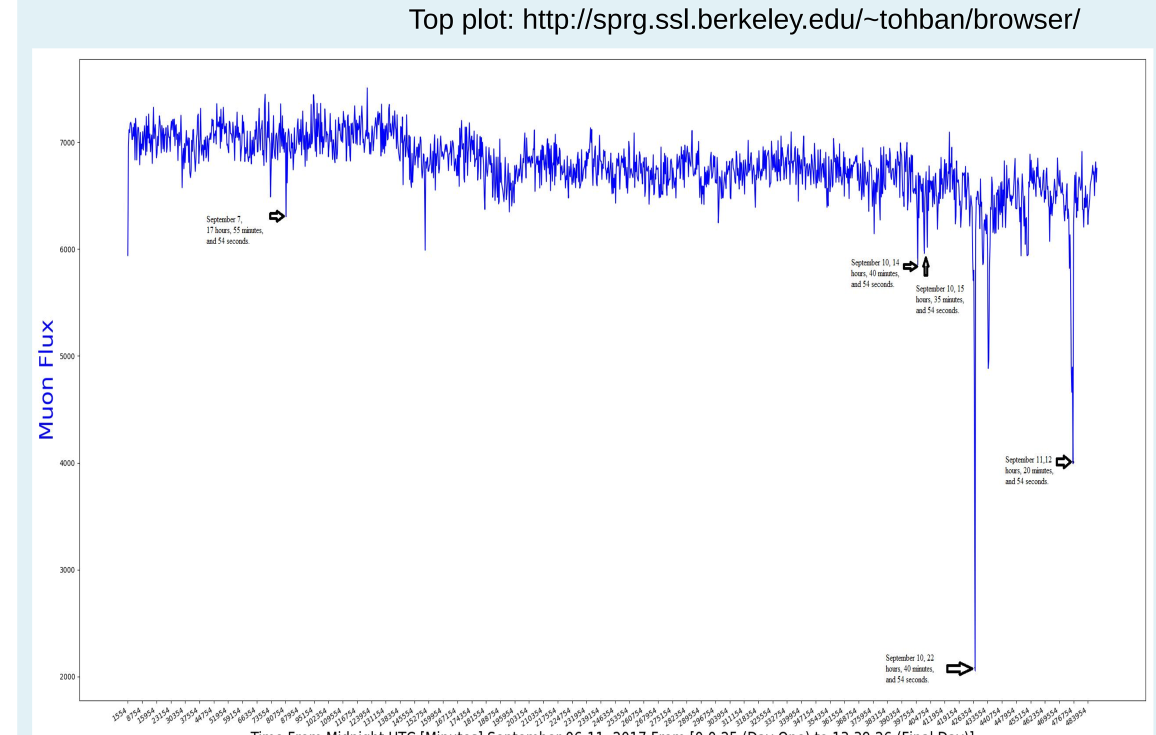
Conclusion

As atmospheric pressure changes muon flux changes, they are inversely correlated and large fluctuations are evident. Large drops in flux were also measured after several solar flares in September 2017.





Top plot: http://sprg.ssl.berkeley.edu/~tohban/browser/



Top left plot: GOES-13 satellite data shows after a solar flare on Sep. 11th the proton flux increase. Top right: GOES-3 satellite shows X-ray flux increases around 1530 UTC on Sep. 10th after a solar flare. Bottom plot: from 1500 UTC Sep. 10th the muon flux measured at QCC with the QuarkNet detector dropped; correlations are being investigated.

Acknowledgements

We thank from QuarkNet Dr. Mark Adams, Ken Cecire and Dave Hoppert; at QCC Dr. David Lieberman, Dr. Tak Cheung, Arkadiy Portnoy and Alexei Kisselev; NSF Space Weather grant NASA MUREP award no. NNX15AV96A

Contact Information

dbuitrago07@tigermail.qcc.cuny.edu
RArmendariz@qcc.cuny.edu

References:

Quark Net cosmic ray detector users manual series 6000 DAQ, J. Rylander et. al., Glenbrook High School, 2010 http://faculty.ucr.edu/~ellison/Quarknet/6000CRMDUserManual.pdf

Funding Source – NSF #1118679 Collaborative Research: Community College Undergraduate Research Initiative (CCURI)