**Abstract**

This project provides an alternative protocol for measuring weather precipitation. The proposed protocol uses the following formula: (absolute value of voltage produced/area of a single precipitation element)/duration of weather event. This produces a numeric value with the units of watts, though it is designated as RPU (rain power units) for sake of clarity. This formula takes into account the correlation between variables, such that a short precipitation event with large droplets and high impact force will not produce the same RPU value as a long precipitation event with similar precipitation element characteristics. Voltage, which was directly proportional to impact force, was measured with a mounted piezoelectric component, while a flour covered tray captured the size of the droplets at the moment of impact. While the RPU value can be calculated for an individual drop, it is better to apply the formula based on the overall average values since it is more useful to look at the weather event as a whole, rather than individual precipitation elements. Altogether, the low equipment cost and simple formula allow for a greatly improved protocol for precipitation measurement.

**The Formula**

**Introduction**

Weather plays a large role in people’s everyday lives. Almost everyone checks the weather before going outside or planning events. However, there are very few ways of measuring and presenting the data. This is most common with precipitation events such as rain or snow.

Currently there are two primary measurements associated with precipitation: accumulation and precipitation element size. The more common of these two measurements is accumulation which is often seen in weather forecasts and reports. The other measurement (precipitation element size) is not as common, but it often used in estimating the amount of damage that a weather event will cause. Climate data measures several other data types, many of which have few practical uses.

As such, there is a dire need for a better protocol to measure precipitation events, beyond the conventional accumulation techniques. This study, which has an end goal of a more descriptive algorithm for weather measurement, has numerous applications in the world. Some of these include more descriptive forecasts (and therefore planning for predicted events) and a better way to describe previous weather events.

**Objective**

**This study will determine, and then implement an improved protocol for the purpose of measuring precipitation events.**

**Implementation**

A piezoelectric sensor will be used to measure the impact force of rain drops while a flour filled baking sheet will capture the size of the precipitation element upon impact.

Piezoelectric sensor

Flour covered baking sheet

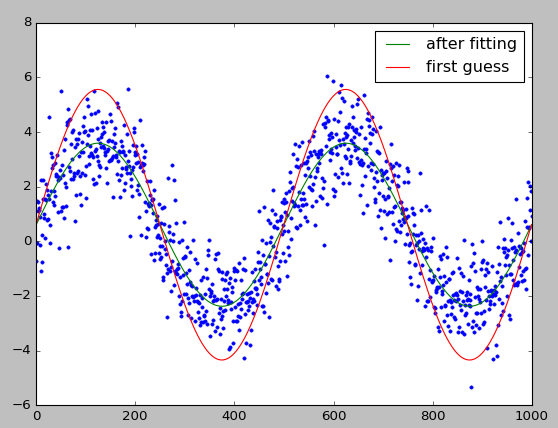
Voltage measurement probe

Wood prop

Angled plate of glass

**Materials and Equipment**

* **Piezoelectric sensor (±5.000 volts)**
* Voltage measurement probe
* Computer with data collection and analysis software
* **Large baking sheet (46 by 33 cm minimum)**
* Baking Flour (shifted if possible)
* 12cm x 12cm square piece of flat glass
* Writing implement and paper
* Small piece of wood (5cm thickness)
* Length measurement device (0.001 meter precision)

****

**Graphed Output of Sine Regression Code**

**Conclusions**

The improved protocol for precipitation measurement performed phenomenally. The RPU formula allows for more aspects of the precipitation event to be recorded and it also accounts for the interaction between them. Consequently, this protocol for measurement is far superior to the current size and accumulation methods. However when conducting research on subjects relating to and/or making use of these techniques, the ideal method would be to employ all three. This would allow result in the most complete result possible. In conclusion, this new RPU precipitation protocol is superior to current precipitation methods, though it should be used in conjunction with them.

**Further Research**

With regards to further research, there are three primary objectives. The first is to incorporate the area measurements and voltage measurements into one device. This would allow for data to be collected for each individual drop thus giving a more accurate RPU value for that drop. The current setup has the area measurement and voltage measurement separate and in future research those processes should be consolidated into one device.

The second objective of further research would be to implement the sine regression program into the data. Currently, the program is able to determine a best fit sine regression for that data and graph it. However, it cannot apply that to the data, nor export the actual equation for the line. In future research, this program should be applied to the data, allowing for faster and more accurate analysis.

The third objective of further research would be to add more variables to the RPU formula. At the time of writing this paper, the formula only takes into account impact force, area, and duration. Precipitation elements have other characteristics that are not accounted for within the formula, and should be in later iterations.

**Applications**

On the surface, this protocol does not appear to have very many applications. However, due to the unique nature of the RPU formula, this new and alternative precipitation protocol has a myriad of applications.

* **Engineering-** A RPU value is essentially a measure of the energy of the precipitation element/event, so engineers can adjust their projects according to the required RPU strain. Currently, projects are often based on accumulation values, which are not a reliable measure of stress. With the implementation of this protocol, engineering safety practices could change drastically.
* **Weather Analysis**- Having a better method of precipitation measurement will allow climate scientists to better categorize and analyze weather events. Ergo, the scientists will have a more complete model/record of any events they wish to study.
* **Weather Prediction-** If meteorologists can provide an RPU estimate for the weather event, people can prepare accordingly since RPU provides information about the weather event’s duration, intensity, and precipitation elements.

**References and Works Consulted**

Ailsa Allaby and Michael Allaby. "raindrop." A Dictionary of Earth Sciences. 1999. Retrieved March 16, 2016 from Encyclopedia.com: http://www.encyclopedia.com/doc/1O13-raindrop.html Simple definition of a raindrop

Austin, P. M. (1947, August). Measurement of Approximate Raindrop Size by Microwave Attenuation [Scientific Paper]. In AMETSOC Journals. Retrieved January 2, 2016, from http://journals.ametsoc.org/doi/pdf/10.1175/1520-0469(1947)004%3C0121%3AMOARSB%3E2.0.CO%3B2 Details a method of measuring raindrop size using microwaves

CoCoRaHS - Community Collaborative Rain, Hail & Snow Network. (1998). Retrieved January 2, 2016, from http://www.cocorahs.org/Content.aspx?page=measurerain How to read rain gauges

How to Measure Rain. (n.d.). Retrieved January 2, 2016, from http://www.wikihow.com/Measure-Rain Describes a common method of measuring rainfall

Imaoka, K. , Japan Aerospace Exploration Agency. (2014 Feb, 17). Global Precipitation Measurement (GPM): an international mission for measuring global precipitation. The 51st session of the Scientific and Technical Subcommittee of COPUOS [Presentation- Vienna, Austria ]. Retrieved January 2, 2016, from http://www.unoosa.org/pdf/pres/stsc2014/tech-41E.pdf Presentation detailing the relevance of the NASA GPM mission and its objectives.

Kubota, T., Yoshida, N., Urita, S., Iguchi, T., Seto, S., Meneghini, R., . . . Oki, R. (2014, September). Evaluation of Precipitation Estimates by at-Launch Codes of GPM/DPR Algorithms Using Synthetic Data from TRMM/PR Observations (Scientific Paper, Earth Obs. Res. Center, Japan Aerosp. Exploration Agency, 2011). IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 7(9), 3931-3943. First given at the International Geoscience and Remote Sensing Symposium (IGARSS), 2011 IEEE International

Lemone, P., Dr. (2013). Measuring rainfall – it’s easy and difficult at the same time [Web log post]. Retrieved January 2, 2016, from http://scied.ucar.edu/blog/measuring-rainfall-–-it’s-easy-and-difficult-same-time-0 UCAR Center for Science Education- details the difficulties of precipitation measurement

Marshall, J., PhD. (2016, February 12). How Is Rainfall Measured? [Web log post]. Retrieved February 18, 2016, from http://www.quickanddirtytips.com/education/math/how-is-rainfall-measured Details the various methods of rainfall measurement

McClymont, A. (2013). Raindrop 2013 [Art project that examined the properties (focus on shapes) of rain drops]. Retrieved January 2, 2016, from http://www.alistairmcclymont.com/artwork/raindrop Based on an experiment at the University of Manchester in the early 1970s performed by C. P. R Saunders and B. S. Wong.

Measuring the Rain. (2002). Retrieved January 2, 2016, from http://www.infoplease.com/cig/weather/measuring-rain.html Describes rainfall/snowfall conversions

NASA’s Real World: Measuring Raindrops. (n.d.). Retrieved January 2, 2016, from https://www.nasa.gov/pdf/462953main\_RW6-MeasuringRaindrops\_508.pdf NASA guide on how to measure raindrops with explanations

National Aeronautics and Space Administration, Global Precipitation Measurement Core Observatory. (n.d.). Dual-frequency Precipitation Radar [Press release]. Retrieved January 2, 2016, from http://pmm.nasa.gov/gpm/flight-project/dpr Overview of one of NASA's precipitation measurement devices on their GPM observatory

National Aeronautics and Space Administration, Sharing Earth Observation Resources eoPortal Directory. (n.d.). Https://directory.eoportal.org/web/eoportal/satellite-missions/g/gpm [Press release]. Retrieved January 2, 2016, from https://directory.eoportal.org/web/eoportal/satellite-missions/g/gpm Detailed report of NASA's GPM mission including diagrams, specifications and processes

NOAA Satellite Research to Operations Transition Survey for Global Precipitation Measurement (GPM) Mission. (n.d.). Retrieved January 2, 2016, from http://www.nws.noaa.gov/mdl/RITT/lotm/docs/GPM\_transition\_survey\_V1.0.pdf Detailed objectives and planned execution of the NASA GPM mission

Pearson, J. E., & Martin, G. E. (1957, November). An Evaluation of Raindrop Sizing and Counting Techniques (Rep.). Retrieved January 2, 2016, from Illinois State Water Survey and University of Illinois website: http://www.isws.illinois.edu/pubdoc/cr/iswscr-10.pdf Discusses various techniques of counting raindrops and their sizes

Rain Gauge. (2006, February 14). Retrieved January 2, 2016, from https://en.wikipedia.org/wiki/Rain\_gauge Details what a rain gauge is and how it works

Stott, H. (May 2014). Colliding Raindrops: How Particles Increase Their Size (Project Thesis for degree of Masters of Engineering). University of Bristol. Retrieved January 2, 2016, from http://seis.bris.ac.uk/~hs0849/Raindrops\_report.pdf Explanation for how raindrops increase in size, as well as their collisions

The Anatomy of a Raindrop. (n.d.). Retrieved January 2, 2016, from http://pmm.nasa.gov/education/videos/anatomy-raindrop Explanation of the parts of raindrops

Tomlinson, C. (2013). A low-cost experiment for determining raindrop size distribution. Retrieved January 2, 2016, from http://www.metlink.org/wp-content/uploads/2013/06/weather\_raindropsize.pdf Provides a way to measure raindrop size at the moment of impact

**Data Analysis**

This table shows the RPU values per second, essentially the combined RPU value of five data points. Looking at the **12.30.15** event, the data shows that there was a high RPU per second, **signifying a large quantity of precipitation elements in one second**. The data also shows that within that event, there was a **high max RPU per second**, meaning that the **elements had a high impact force per unit area**.

From this table, that data shows that overall RPU values are not directly tied to duration of the precipitation event, as intended by the RPU formula. An interesting data point to note are the **12.31.15** event, which shows that a long event can have a **low average RPU value**, but a **high max RPU value** (signifying a **heavy rain at some point** within the event). Also of note is the **12.30.15** event, which shows that a **short and intense event produces very high RPU values**.