A New Detector Array for Studying TGEs in the American Midwest

Lightning Research Group, Monmouth College

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Overview

- Introduction
- Thunderstorms in the American Midwest
- Studying TGEs in the Midwest
- Detector package design
- Future work and Conclusions

Where is Monmouth, IL

Google Maps

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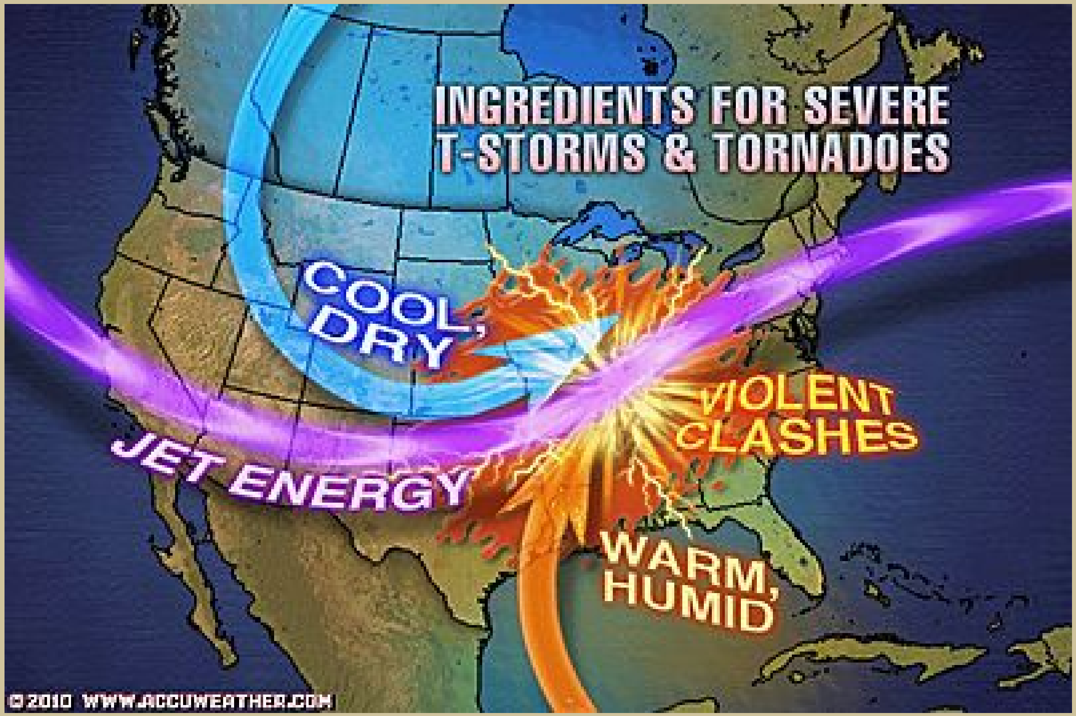
Thunderstorms in the Midwest



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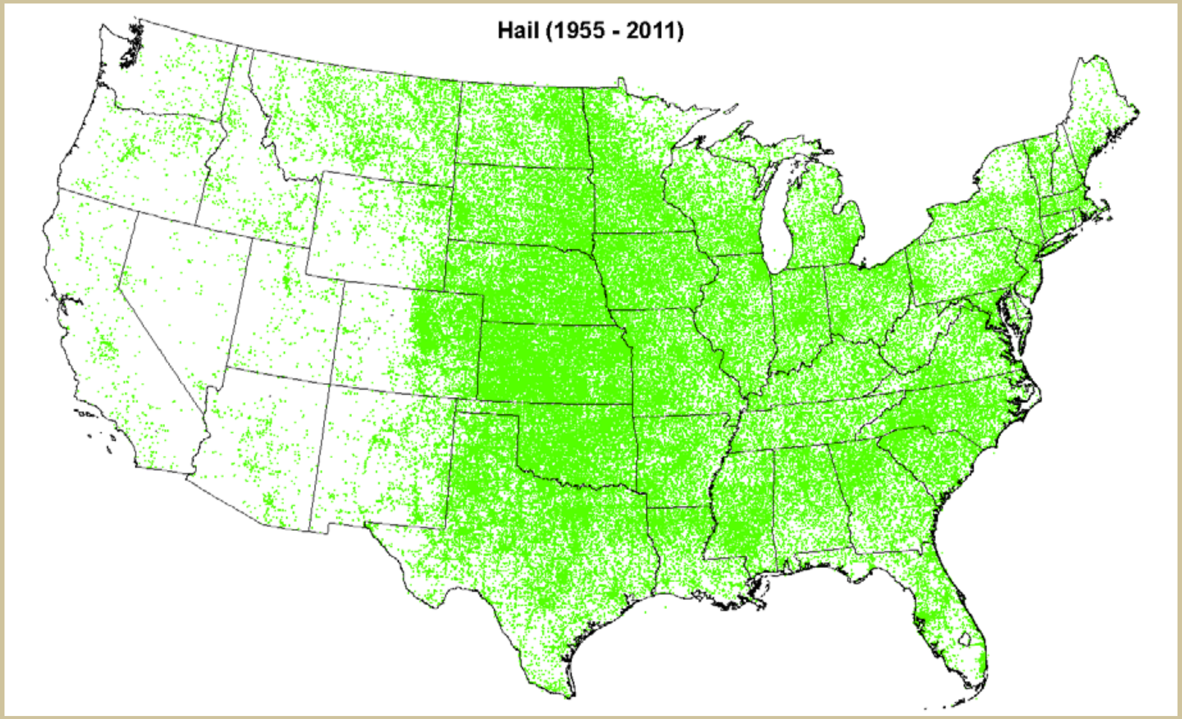
Thunderstorms in the Midwest



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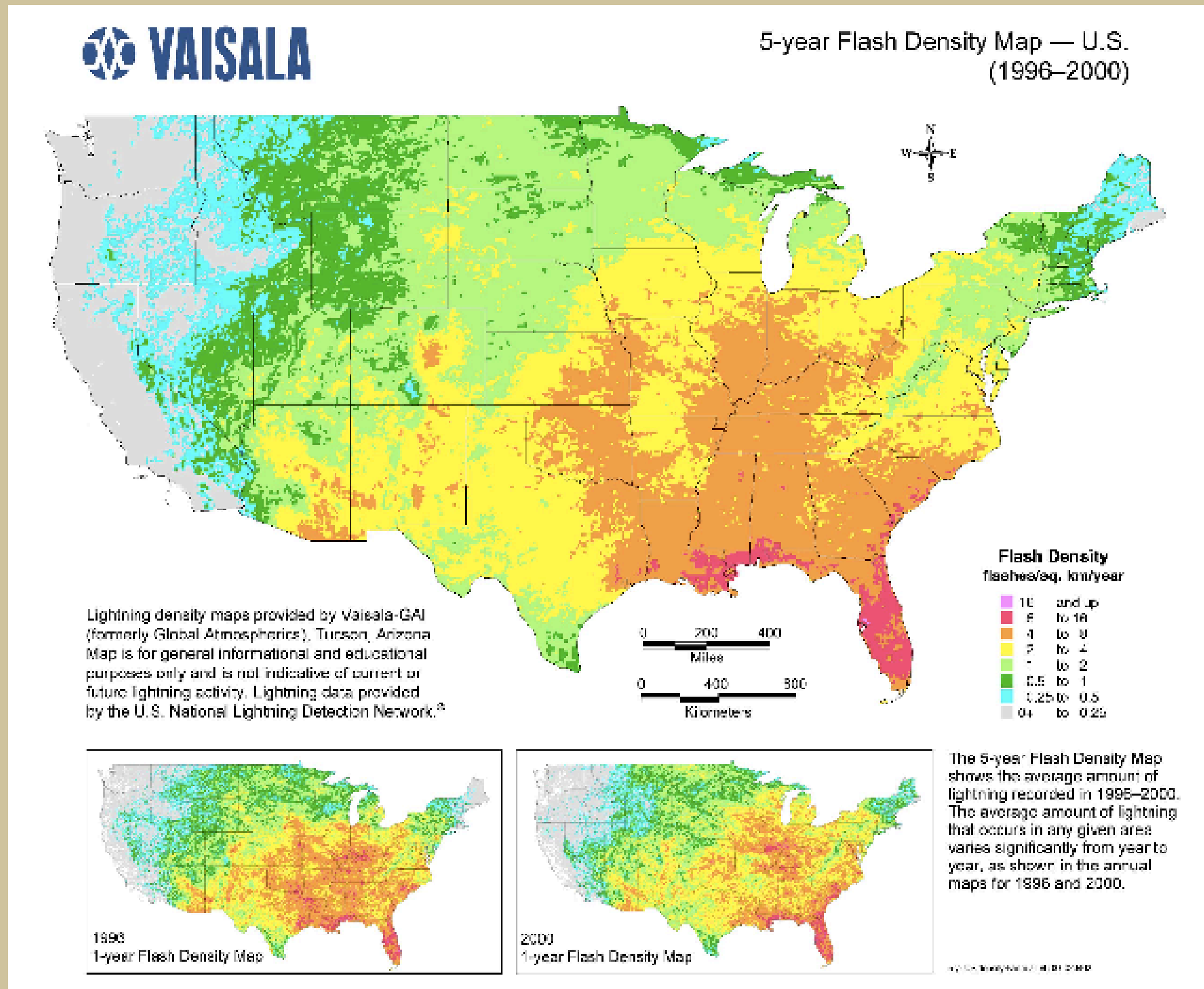
Thunderstorms in the Midwest



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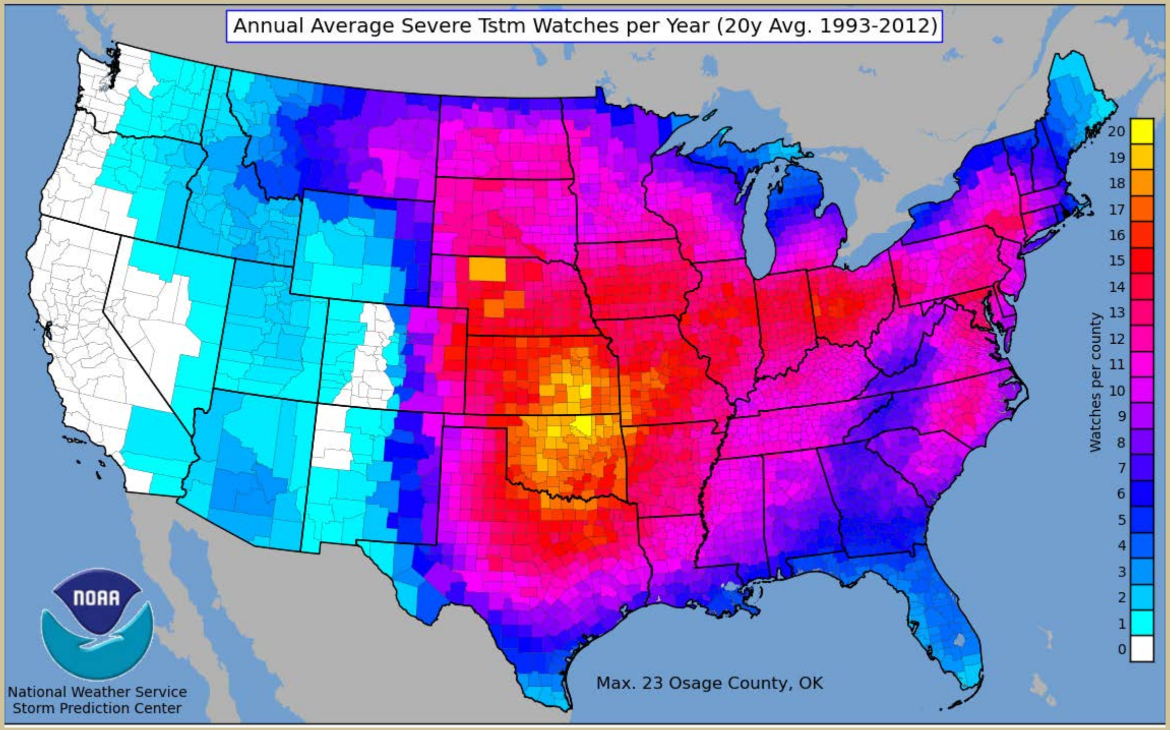
Thunderstorms in the Midwest



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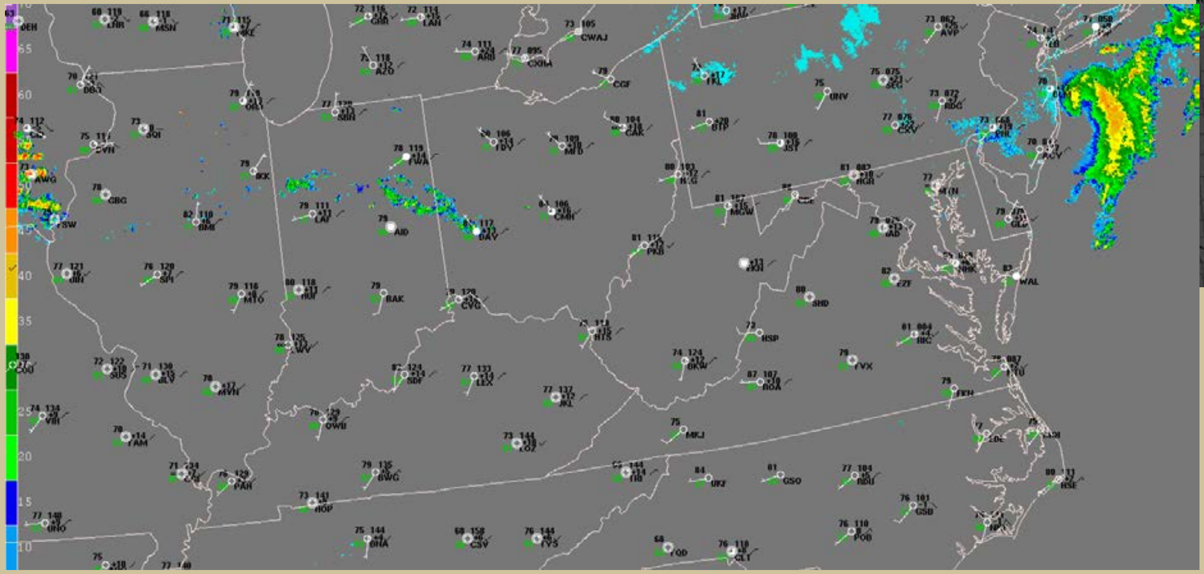
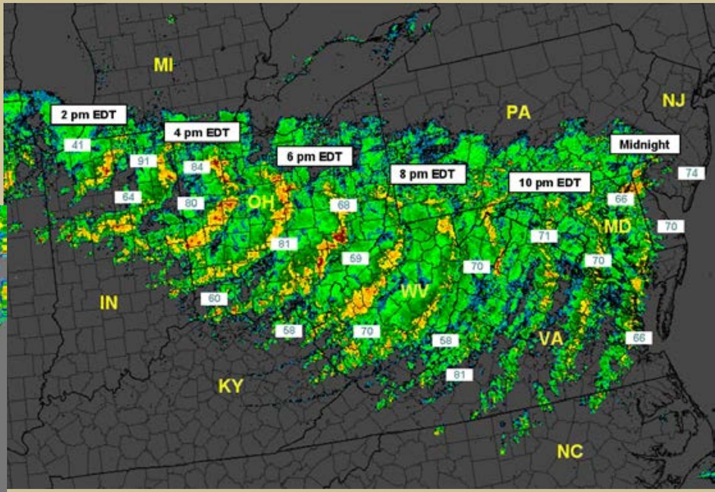
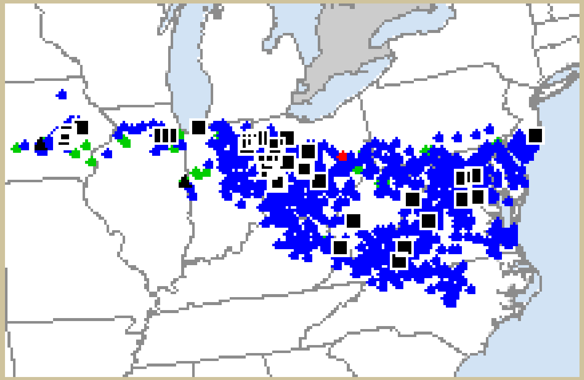
Thunderstorms in the Midwest

Derecho: A long-lived storm with high straight-line winds







http://www.spc.noaa.gov/misc/AbtDerechos/casepages/jun292012page.htm#

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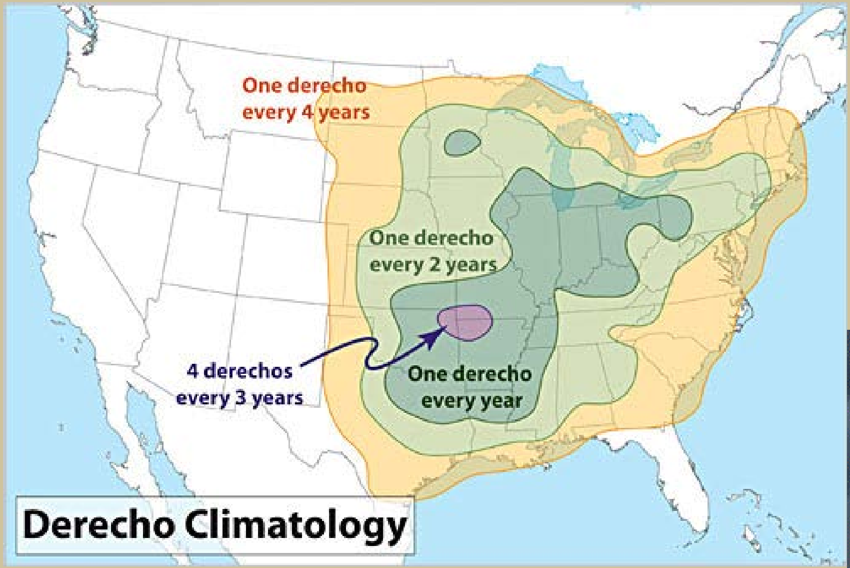
Thunderstorms in the Midwest



http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

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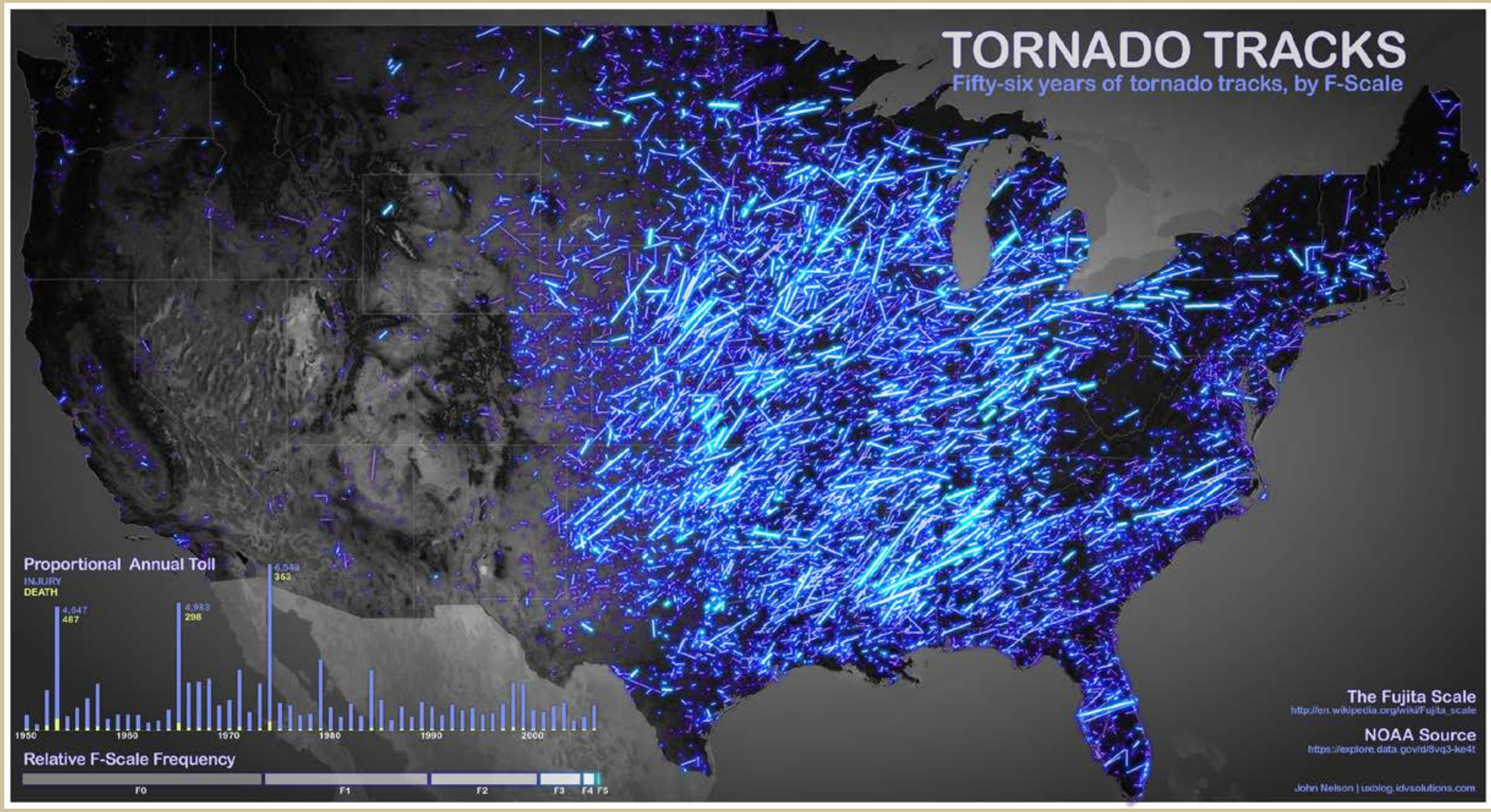
Thunderstorms in the Midwest

Tornadic Thunderstorms



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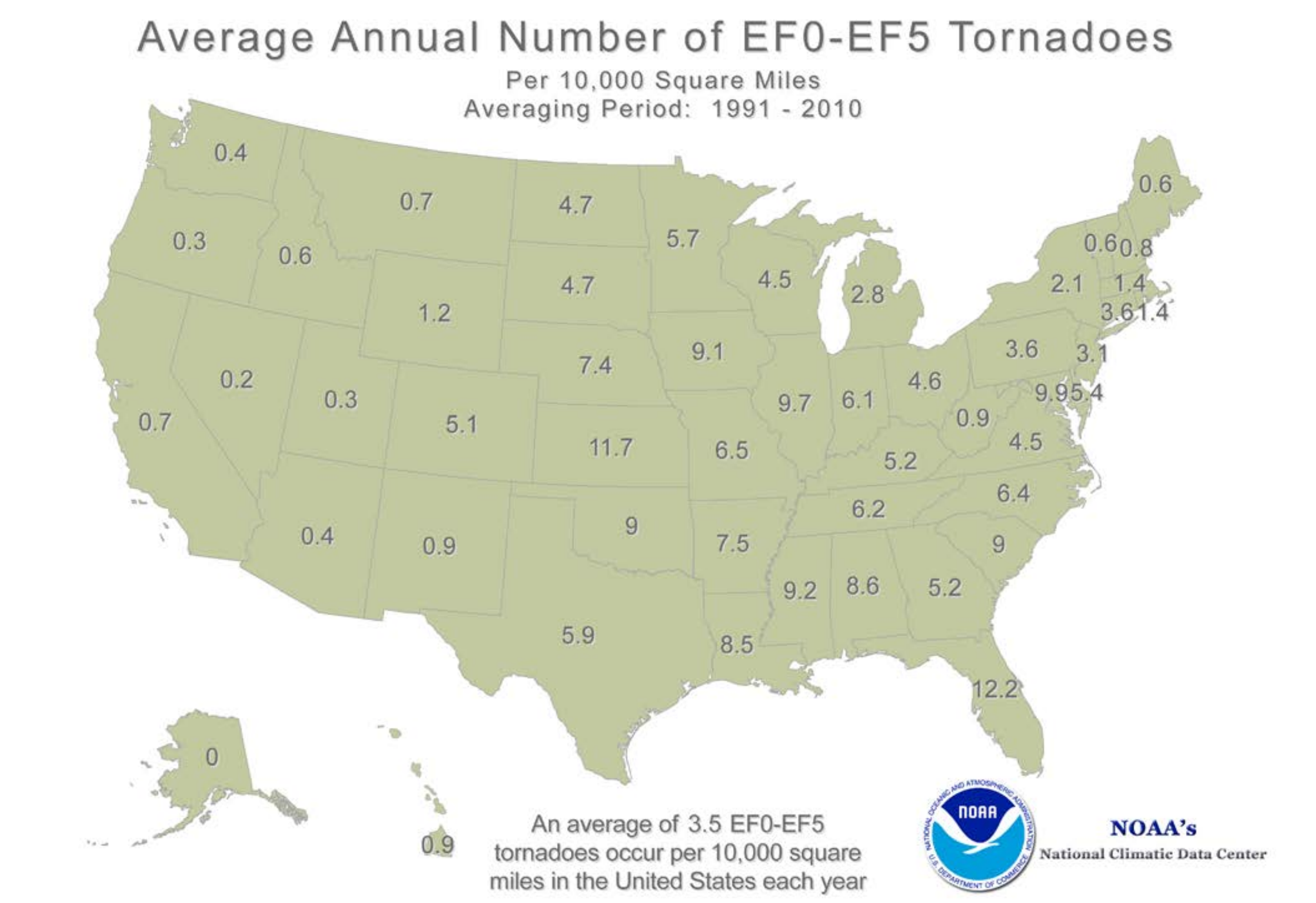
Tornadic Thunderstorms



Studying TGEs in the Midwest

Thunderstorms in the American Midwest have some unique properties. These unique storms raise interesting TGE questions:

- Do these storms produce TGEs with the same frequency? Do they occur as often, more often, or less often?
- Do these storms produce photons with the same energy spectrum? Are these TGEs somehow different?
- Are the processes that produce TGEs in midwestern storms the same as in other storms (like in Louisiana, or Aragats, for example)?
- Can TGEs be used to identify storms that are or will become severe, tornadic, have large hail or produce derechos?
- Can TGEs be used as a tool to examine the dynamics of these storms?

Studying TGEs in the Midwest

Goal: Measure TGEs and the conditions that produce them

- **Measure photons (TGEs) in the energy range from a few keV to ~2 MeV**
- **Record lightning strikes (to match with WWLLN)**
- **Record pressure, temperature, and relative humidity, sound (and possibly other meteorological conditions/parameters)**
- **GPS timing of events (RTC backup)**
- **Measure E-Field**

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Studying TGEs in the Midwest

Design Considerations:

Coverage: Deploy as many detectors deployed as possible and detect photons from any source.

Background: We need to measure and or control backgrounds.

Cost and reliability: Many detection packages requires low cost per package

Flexibility: Use off-the-shelf hardware to allow the addition of additional sensors and capabilities while maintaining low cost.

Studying TGEs in the Midwest

A Wide-Area Array of Detectors to Measure the Energy Spectrum of TGE photons

- We have built 10 detector packages that we will be deploy over a large area in western Illinois and eastern Iowa (~100 sq. km)
- By having many detectors, we improve our ability to capture the TGE photons that are produced.
- High reliability and low cost mean that detectors can run for many years.
- A “WWLLN” for TGE detection….

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Studying TGEs

Measure photons (TGEs) in the energy range from a few keV to ~2 MeV

- NaI/Photomultiplier tube combination
- Canberra NaI 2x2 (5.1 cm x 5.1cm) with PMT (8.5% resolution)
- Calibration with nearby ^{60}Co source while deployed

Canberra Osprey Base:

- Power over Ethernet
- Built-in MCA
- Communication over Ethernet
- External control via GPIO pins
- Data accessible via Python Libraries
- Built-in Web Server

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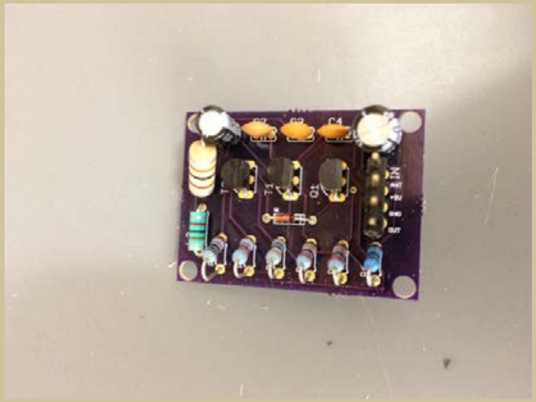
Record lightning strikes (to match with WWLLN)

- Simple RF detector from http://www.techlib.com/electronics/lightning.html#Lightning%20Simulator
- Circuit detects broadband RF and puts out a well-defined logic pulse
- External Antenna input controls gain
- We designed a PCB board to simplify construction and make the system modular



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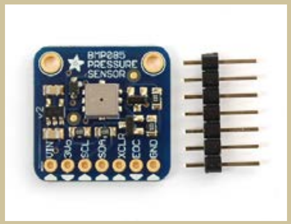
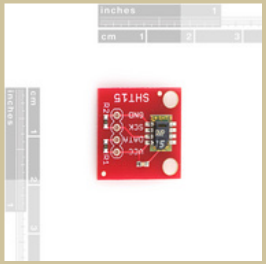
Record pressure, temperature, and relative humidity, sound (and possibly other meteorological conditions/parameters)



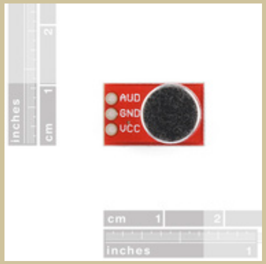
Pressure-Temperature Sensor: Adafruit BMP085

- Absolute accuracy of 2.5hPa and a noise level of down to 0.03hPa (which is equivalent to an altitude change of merely 0.25m)
- Ultra low power consumption of down to 3μA
- Pre-calibrated



Humidity-Temperature Sensor: Sparkfun SHT15

- Accuracy of 2% (Relative humidity)
- Power consumption of $90\mu W$ @ 5 V
- Pre-calibrated



Electret Microphone Sparkfun

- Simple Analog out microphone

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- **GPS timing of events (RTC backup)**

GPS (I2C Bus): DSS Circuits

- GTPA010 with embedded antenna
- Low power consumption (55 mA@acquisition, 40 mA @ tracking
- Ultra-High Sensitivity
- Update rate up to 10 Hz

Real Time Clock (RTC) DS1307: Sparkfun

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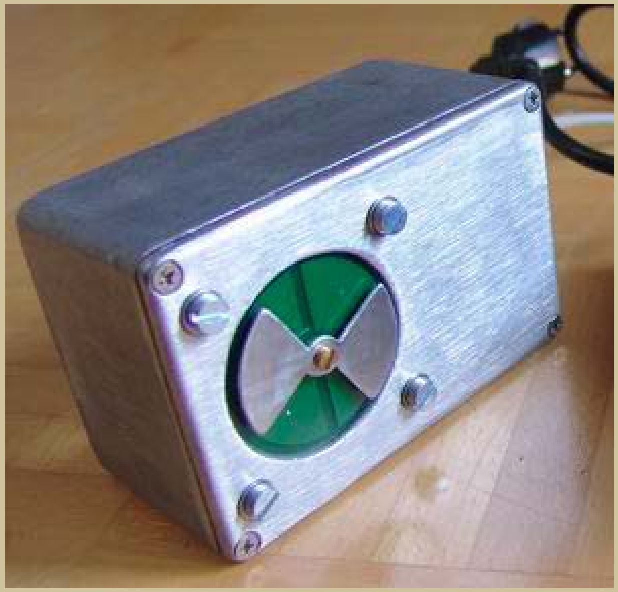
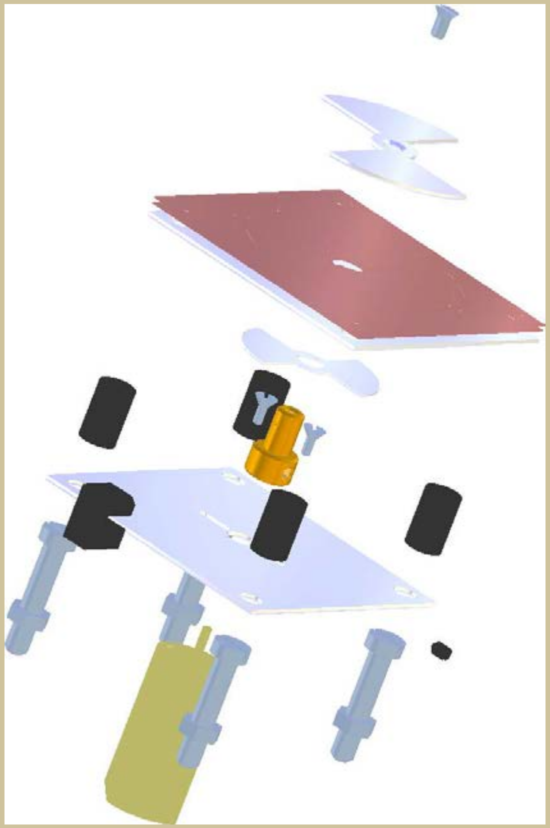
Measure E-Field





E-Field Mill Constructed (Ihninger et al.)

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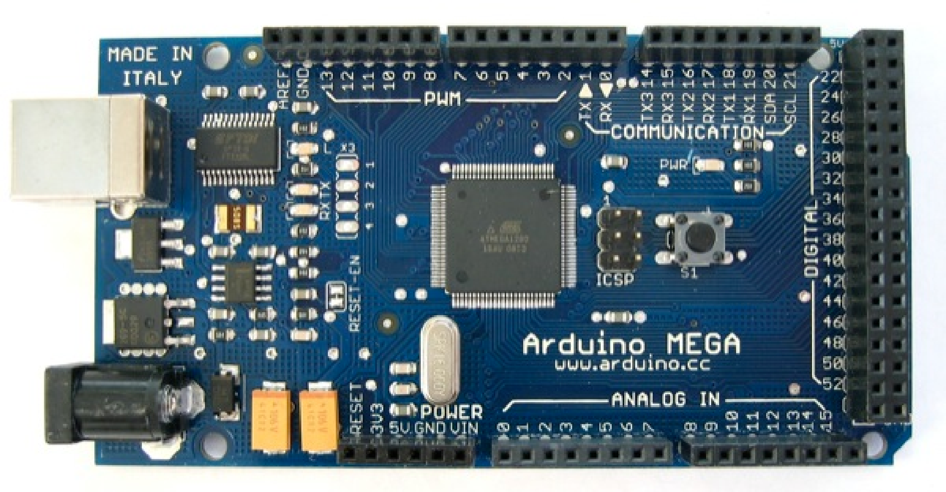
<u>Micro ControllerArduino Mega</u>

- Inexpensive microcontroller
- Low power consumption, digital and analog pins that can be configured for input or output
- Standardized design with open Eagle Files
- Array of options including power over ethernet
- Programmable over USB using a C like environment
- Built-in interrupt handling.



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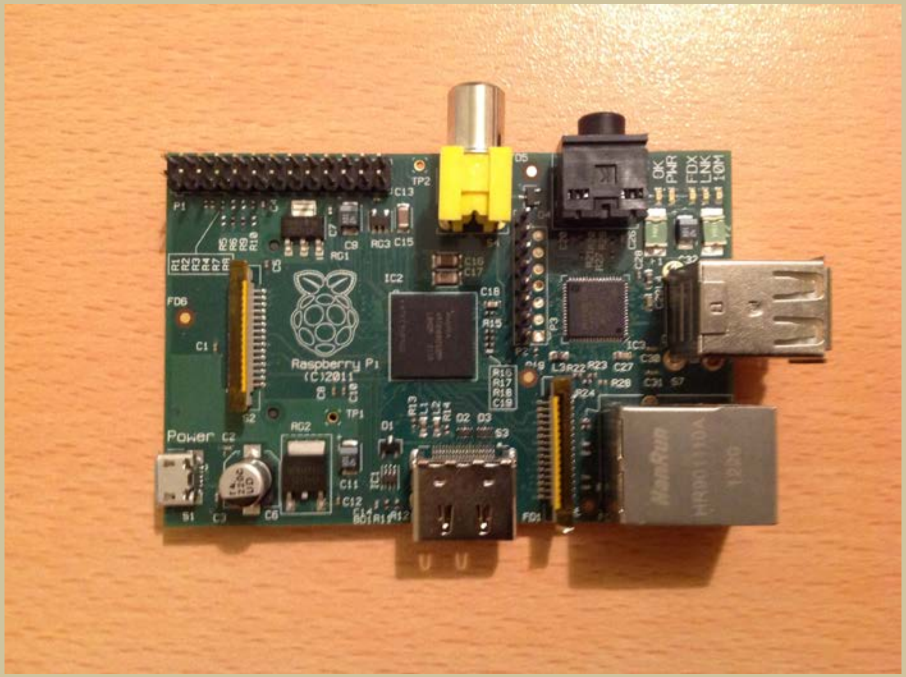
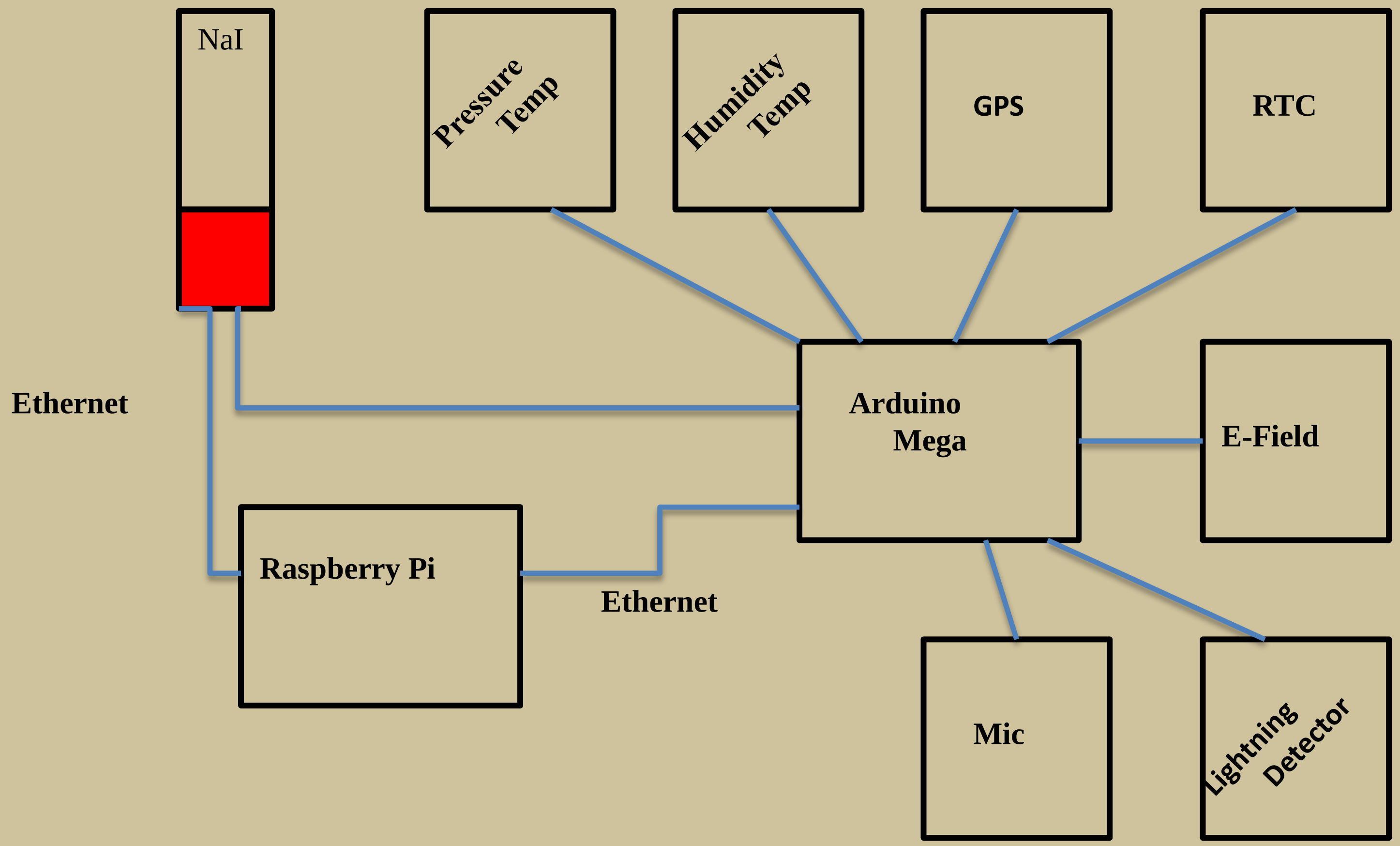
Manage the User interface/Data Recording/Talking to the Arduino



Raspberry Pi:

- 100M Ethernet
- 512 M RAM
- Linux OS (Raspbian) on SD card
- HDMI, Audio, USB ports
- Low power use
- GPIO pins
- Only $35

Measuring TGEs: How it all fits together



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Operation

- Lightning detector detects RF pulses and sends logic pulses for each strike to microcontroller (or manual start is issued).
- Microcontroller process logic pulses from the lightning detector as interrupts, recording pulse length and time of occurrence.
- Microcontroller computes a strike rate. If strike rate exceeds a preset threshold, the Microcontroller sends a logic pulse to the Canberra Osprey base to begin recording data
- When NaI/Base is triggered, sensors begin recording every time interval
- Sensors feed Arduino, which in turn writes to Raspberry Pi.
- Arduino logs data to a separate on-ethernet microSD card
- Raspberry Pi records data and updates User Interface.

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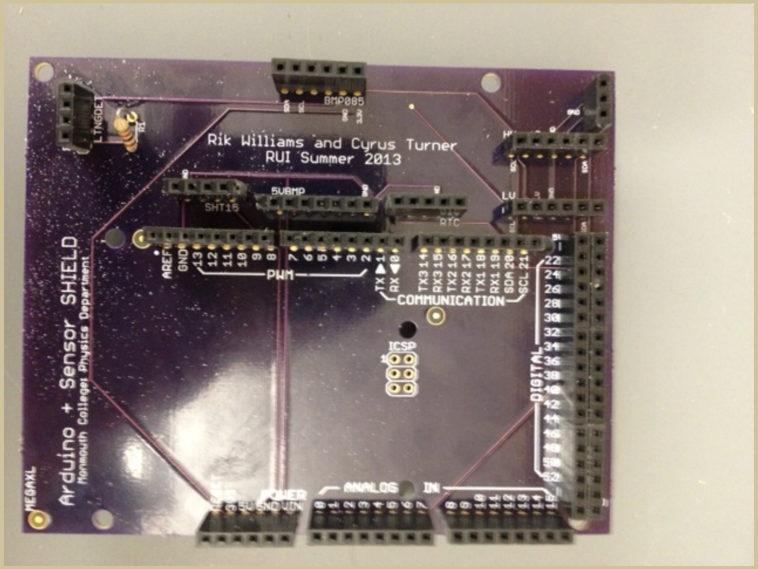
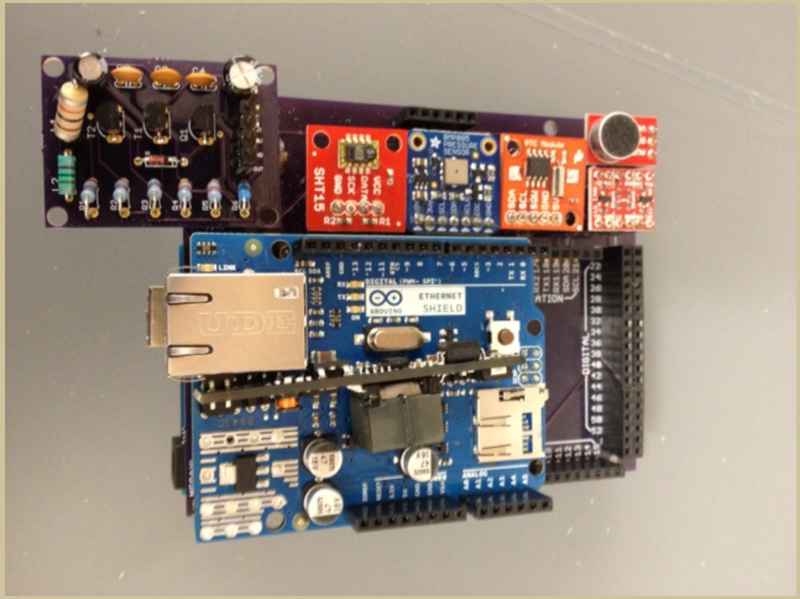
Implementation: Build a Shield for the Arduino Mega

- Wanted a simple, modular design
- Easy to replace sensors
- Compact with short wire runs



"Bare" Shield



Sensors Mounted-Shield Mounted
Power over Ethernet in place.

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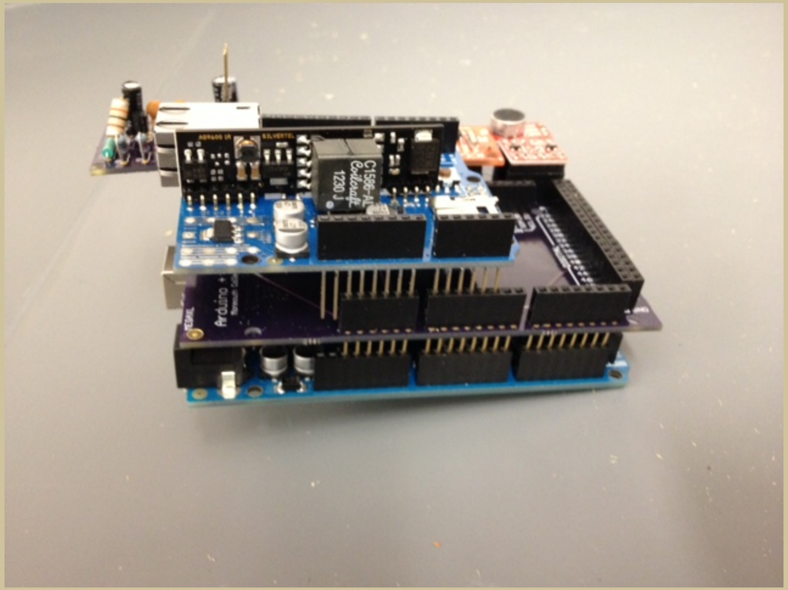
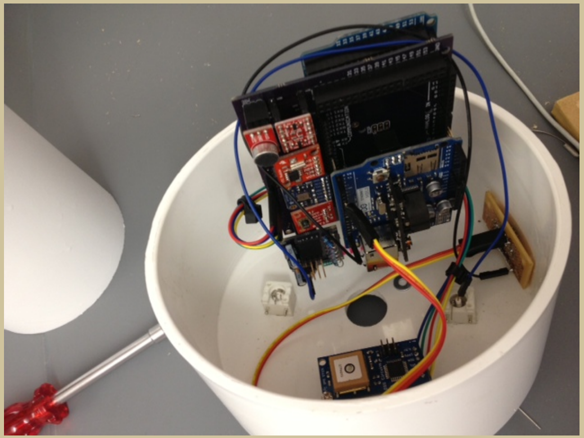
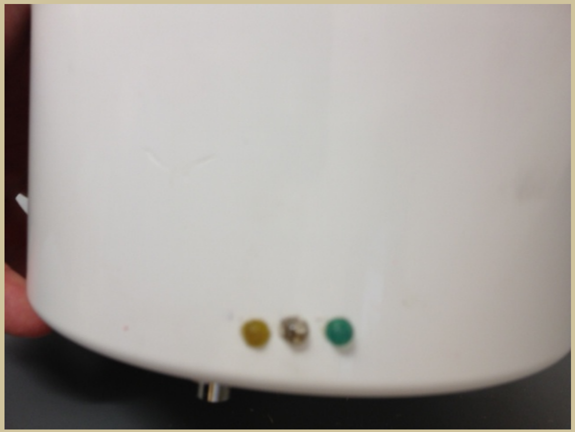


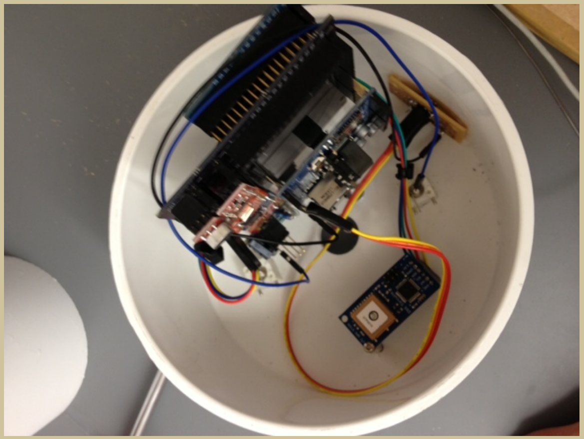
Studying TGEs

Packaging

- Water-resistant but ventilated
- Easy to Assemble
- Easy to service
- Compact and easy to transport and deploy
- Electronics in removable base cap







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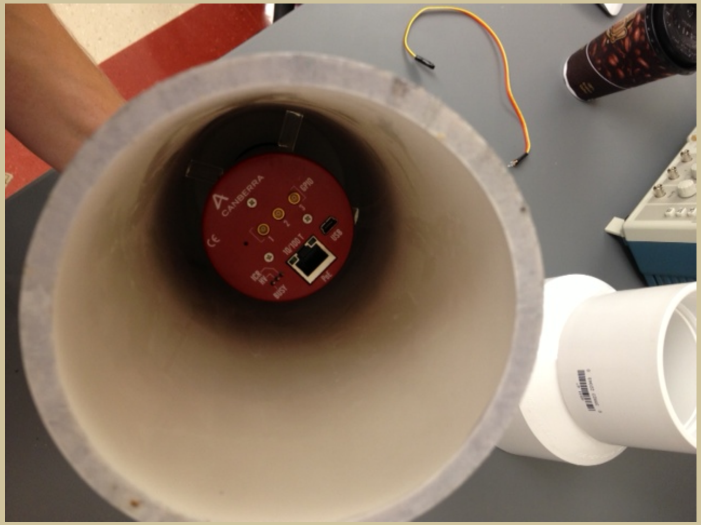
Packaging

- NaI crystal exposed, but remaining parts sealed
- Ventilation-small fan circulates air up through base and out ventilation tubes



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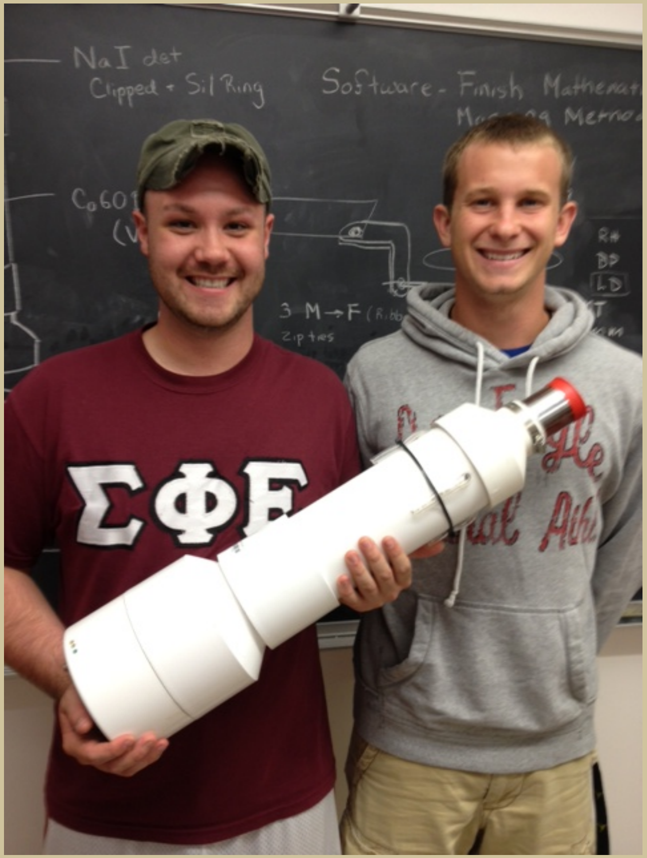
Detector Design: Finished (Almost).



Conclusions and Future Work

This Summer:

- Complete 10 detector packages
- Finish Software
- Deploy at local high schools. Students assist in data collection
- Accumulate data, associate with WWLLN data

Upcoming Year—Next summer and beyond

- Accumulate data and begin analysis
- Repair and upgrade deployed detectors (additional sensors…)
- MCNP/GEANT4 modeling
- Background studies/data analysis
- Upgrade software (automated temperature control)
- Balloons with real-time communication?
- Build more!

Begin to understand TGEs in Midwestern Thunderstorms.

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