Low Cost Weather Stations for Developing Countries (Kenya)

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7th UNSPIDER Conference

23th-25th October 2017

Prepared with support of:

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Outline

- Need for weather data for agriculture and disaster management
- Low-cost 3D-Printed Automatic Weather Station (3D-PAWS)
- Evaluation, testing and calibration results of 3D-PAWS
- Deployment of 3D-PAWS in Kenya
- Linkage with Educational program (GLOBE program)
- Access and visualization of the collected data
- Associated cost of development of 3D-PAWS…

Need for weather data in Kenya

- In Kenya, approximately 75% of the population depend on subsistence farming and its Kenya's most important economic activity
- Common disasters that affect Kenya includes floods, landslides and drought
- As such, there is need to map and predict water and weather patterns for agriculture as well as disaster management.
- EO data provides critical data but there is still need for fusion of this data with in-situ measurements
- To deploy a system of in-situ measurements, there is need for a huge investment in infrastructure and human capacity
- Convergence of technologies of micro-sensors, computing capabilities and wireless communication can provide a framework for in-situ measurements

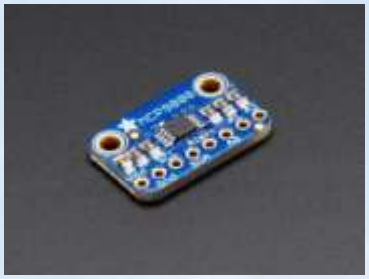
3D-Printed Automated Weather Station (PAWS)

- Uses 3D printers – inexpensive technology
- Use low-cost, reliable micro-sensors
- The system is fabricated, assembled as well as maintained locally
- "Print and replace" components when systems fail
- Enable local agencies to take ownership in building and maintaining observation networks
- Data collected will provide ground-based benchmark and cross calibration standards for multi EO satellite sensors

Weather Station

3D-Printed Automated Weather Station (PAWS)

Radiation Shield and State Variables: Pressure, Temperature & Humidity



Power and Communications

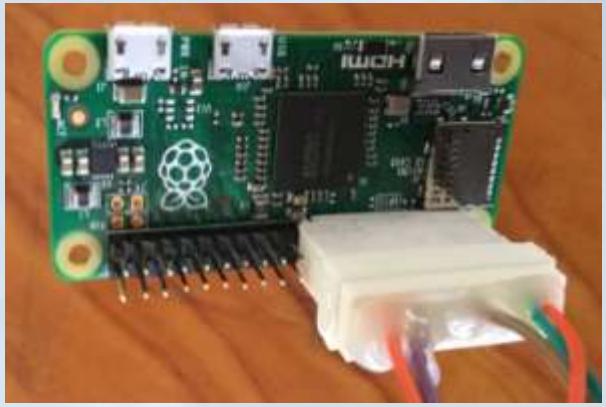
Solar power solutions & Solar Battery

Cellular data communication (m le)

3D-Printed Automated Weather Station (PAWS)

Data acquisition and communication

Raspberry Pi Zero (Single Board Computer)



Wind Direction

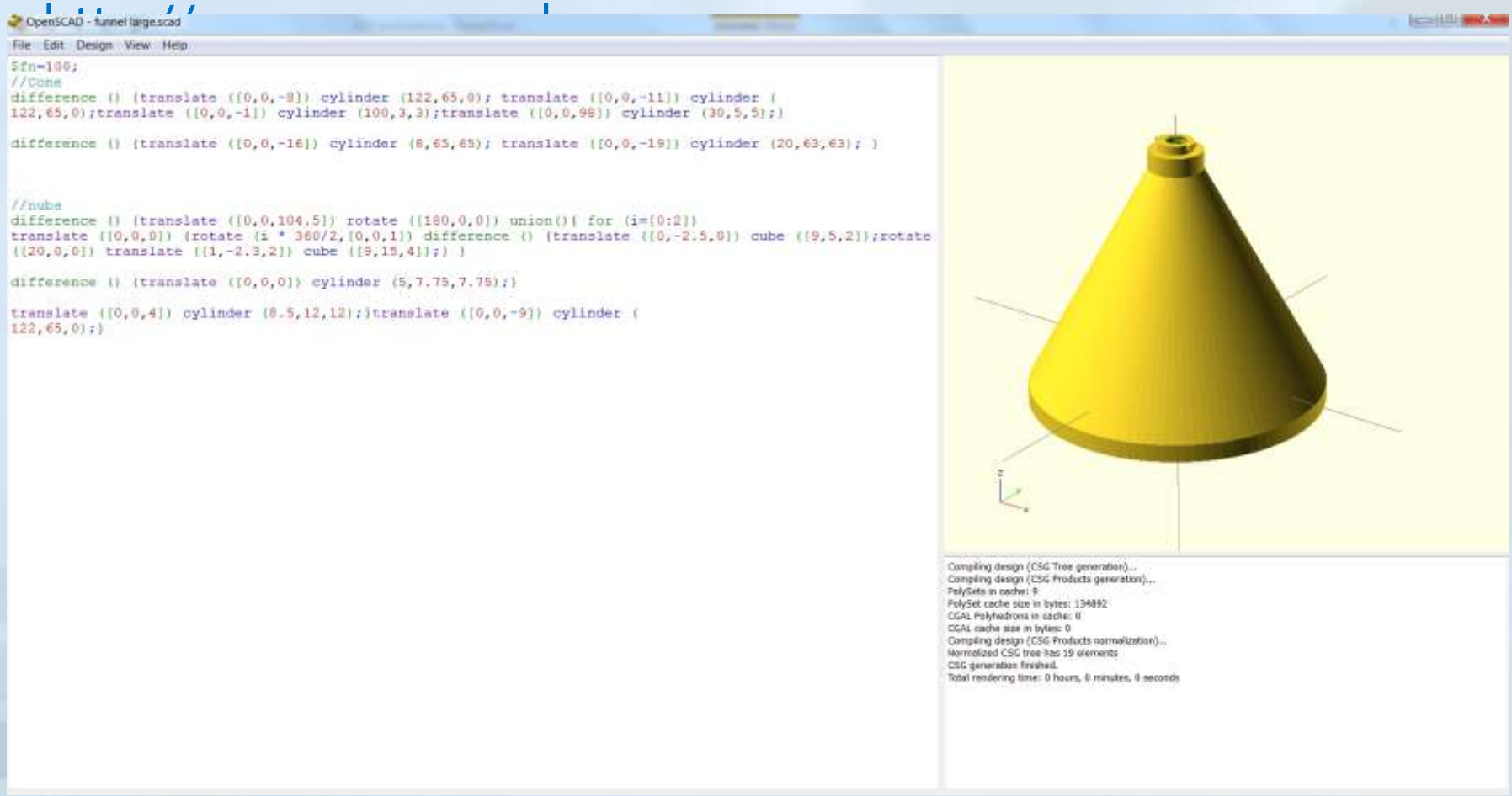
Solar Radiation

Wind Speed

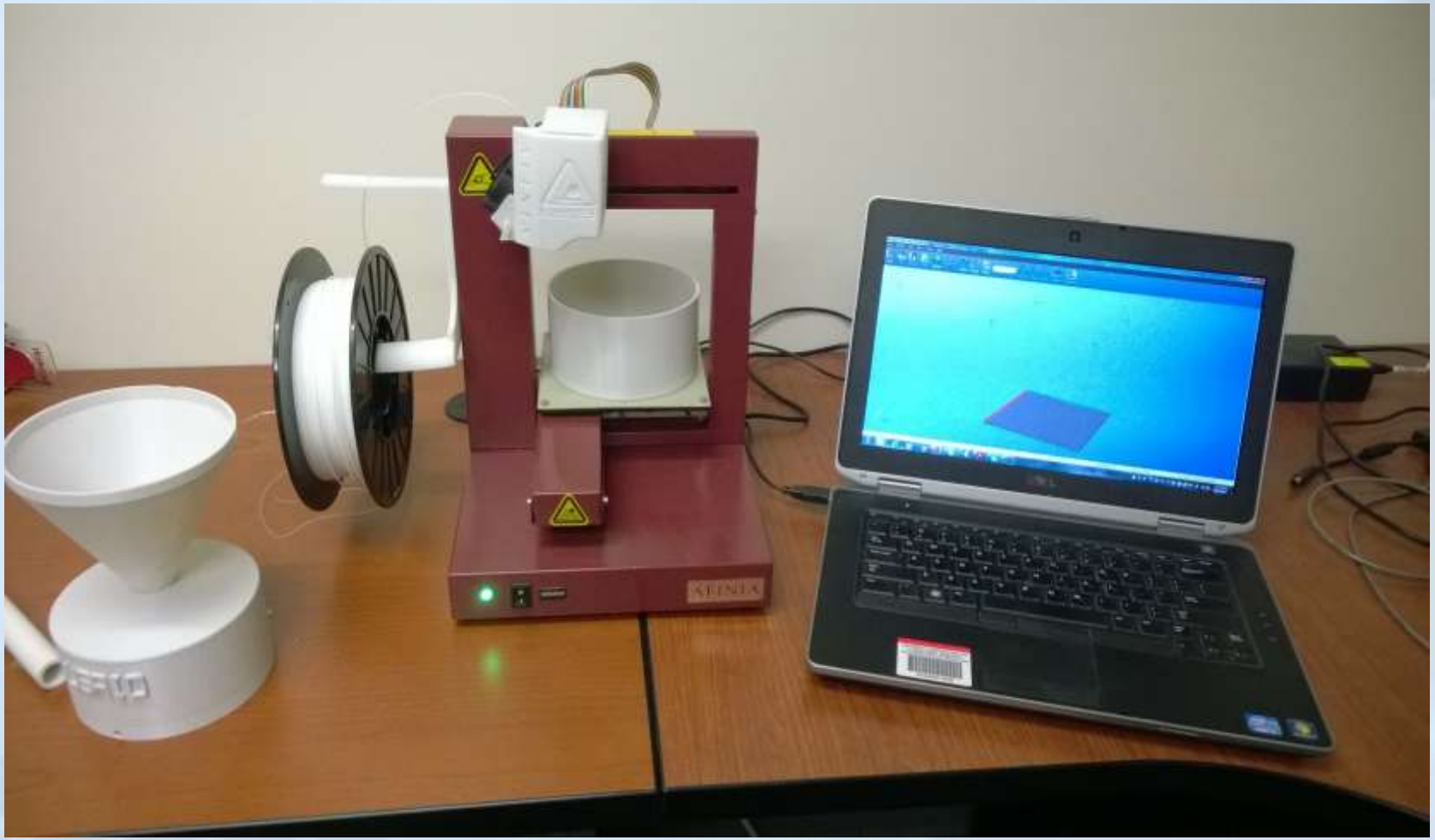
Precipitation Rate

Computer Aided Drawing 3D-PAWS Models Design

Instrument designs are developed using an open source computer aided drawing (CAD) software tool :



Sample 3D-Printer Setup

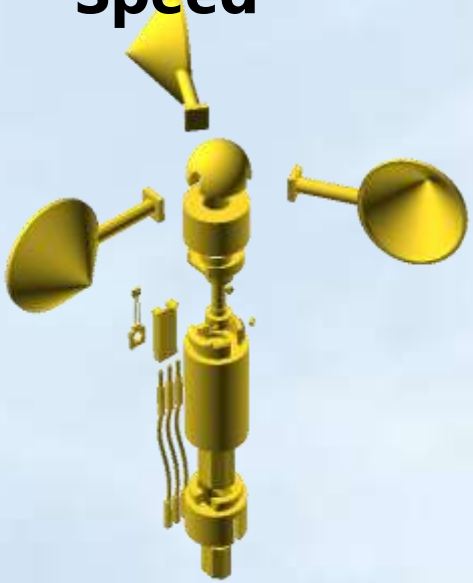


3D Printer, Plastic Filament, and Computer Aided Drawing Software

3D Printed Weather Station Sensor Designs

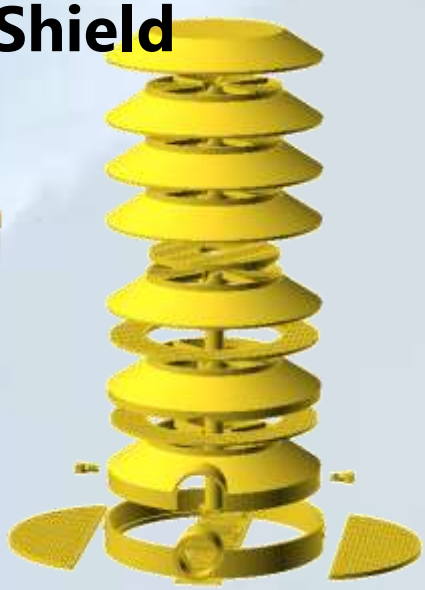
Precipitation

Wind Speed



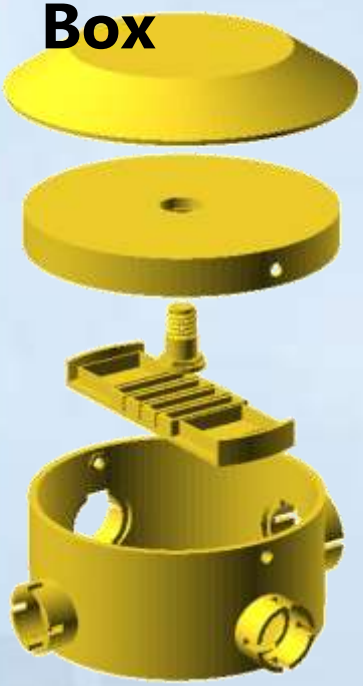
Wind Direction

Radiation Shield

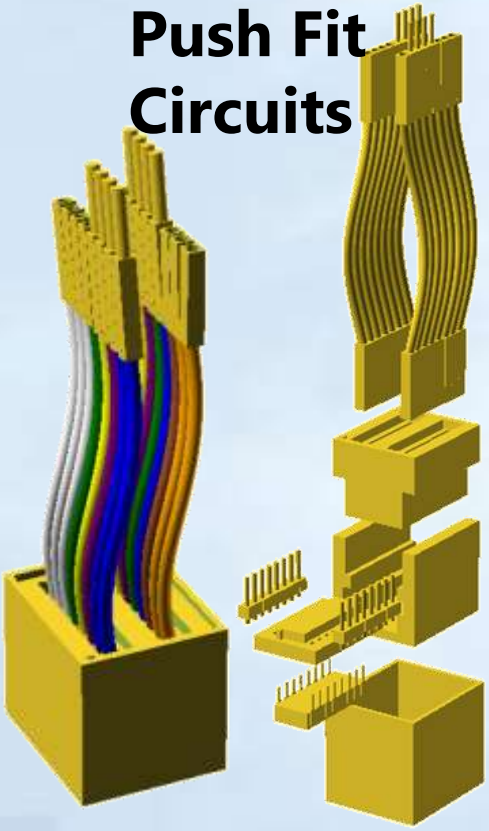


3D Printed Weather Station Component Designs

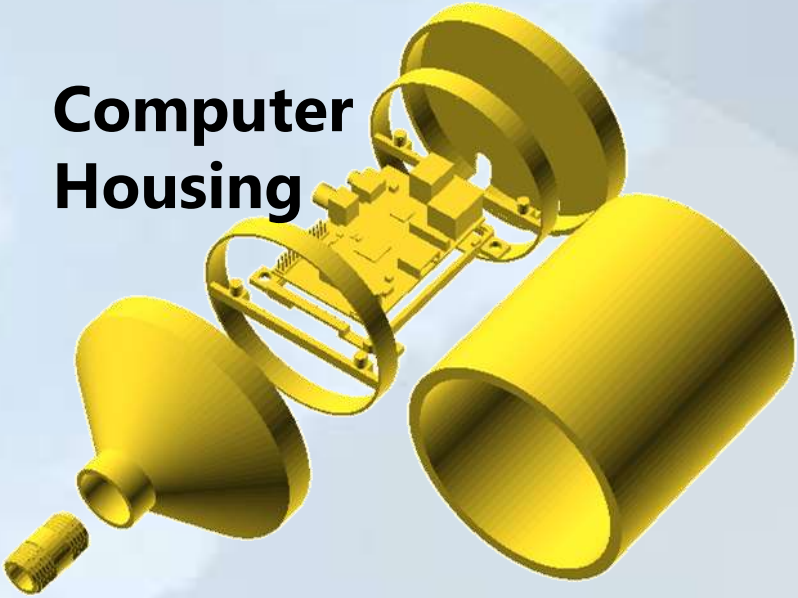
Junction Box



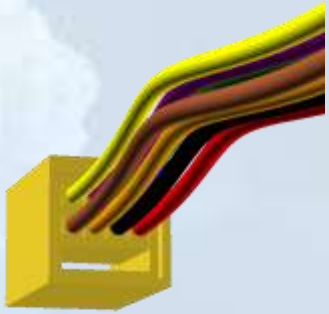
Push Fit Circuits

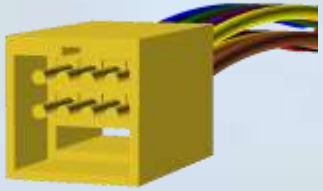


Computer Housing



Connectors





~120 components of the weather station are 3D print

Evaluation, Testing and Calibration of 3D-PAWS

- Sensors calibrated and evaluated testing at the NOAA Testbed in Sterling, VA
  - Calibration & Failure conditions
- Evaluation of sensors is conducted at the NCAR Marshall Research Facility in Boulder, CO and at the NOAA Testbed Center in Sterling, VA
- Sensor observations are being compared with calibrated commercial reference sensors
- Observations are matched at 1-min resolution to compute error estimates of the 3D-PAWS sensors

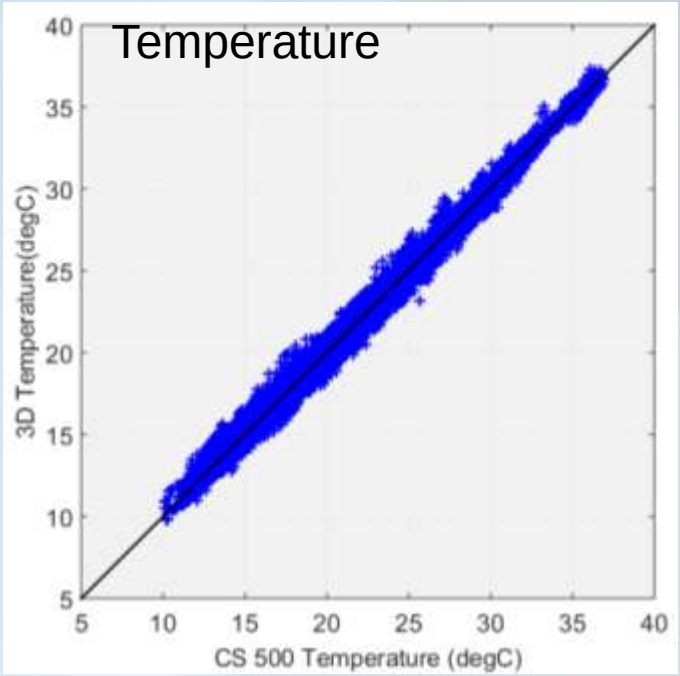
NCAR Testbed

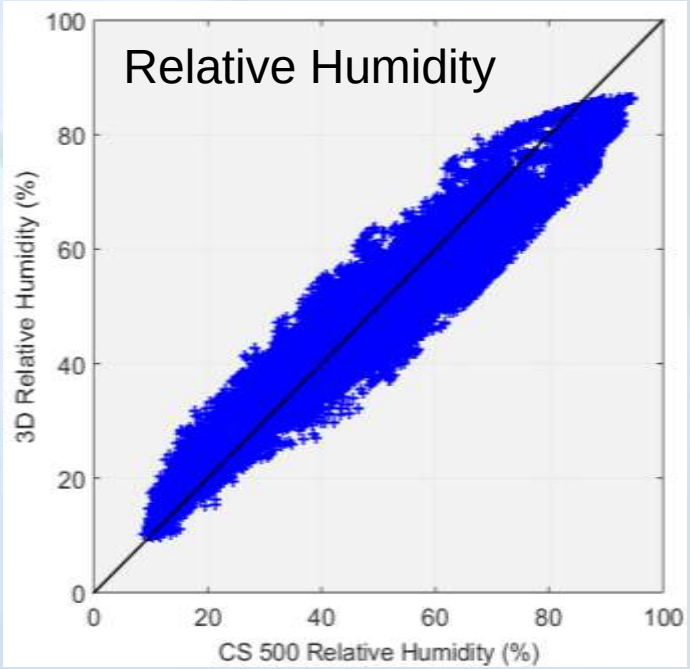
NOAA Testbed

3D-PAWS Evaluation Results

- 3D-PAWS temperature comparison shows good agreement with Campbell Scientific (CS) 500 series sensor
  - Root Mean Squared Error (RMSE) = 0.4° C
- 3D-PAWS Relative Humidity (RH) comparison shows a larger uncertainty with the CS 500 sensor
  - RMSE = 5%
  - Low bias at high RH
  - High bias at low RH

Results from the NCAR Testbed Site





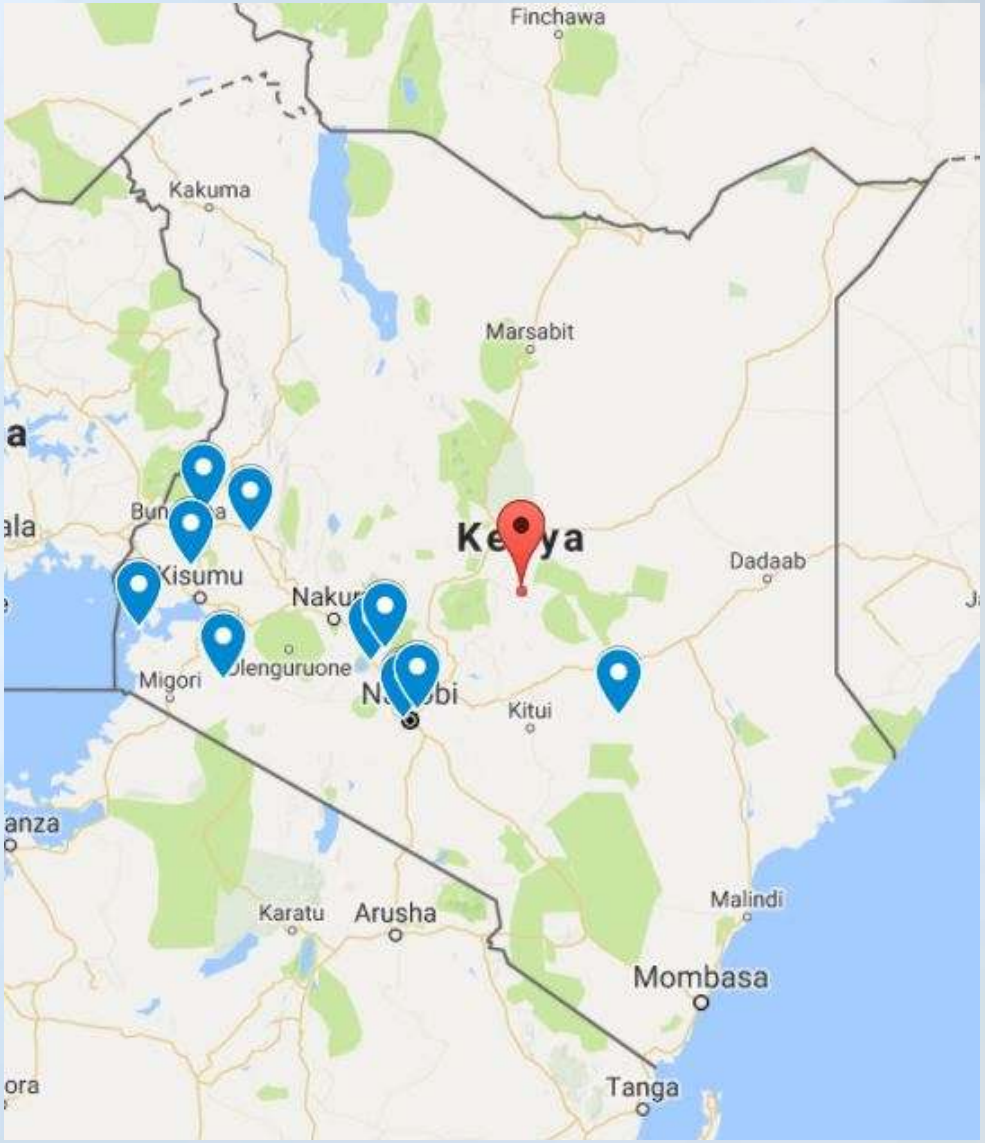
3D-PAWS Deployment in Kenya

11 Weather stations have been installed in GLOBE schools in the following regions;

- Nairobi (2)
- Nakuru (1)
- Nyandarua
- Bungoma (1)
- Uasin Gishu (1)
- Kakamega (1)
- Homabay (1)
- Transmara (1)

Additional stations

- Regional Centre for Mapping of Resources for Development (1)
- Kenya Meteorological Department (1)



Some of the Kenya 3D-PAWS Sites

Naivasha School

Magomano School

Bushiangala Schoo

Connecting 3D-PAWS to GLOBE Program

* GLOBE Program is an international Earth science and Environmental education program.
* GLOBE protocols on Atmosphere, Hydrosphere, Biosphere and Pedosphere (soil) that has generated over **145 million in-situ measurements**.
* Actively involved in validation of data from satellite missions such as cloudsat, GPM, SMAP etc
* Provides a framework for students to collect and

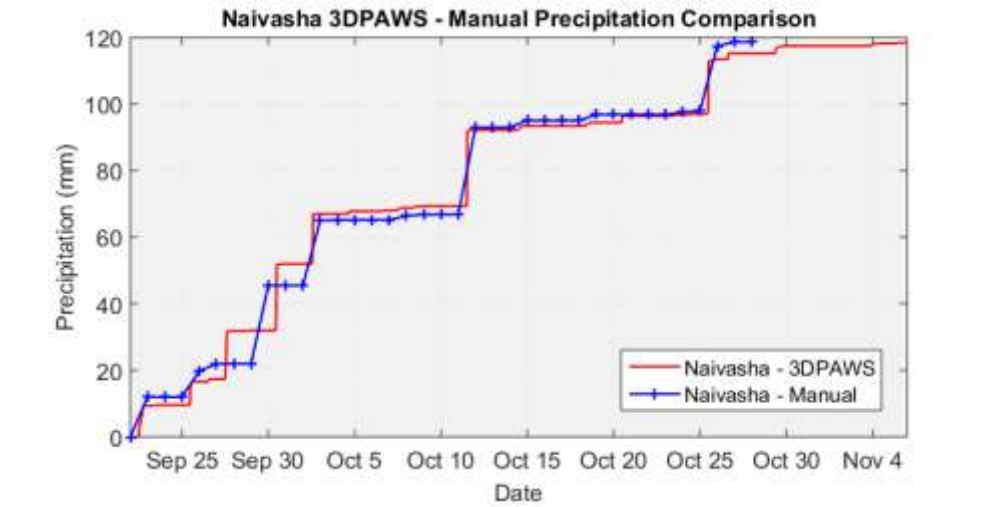
GLOBE Program is supported by NASA and NSF

http://www.globe.gov

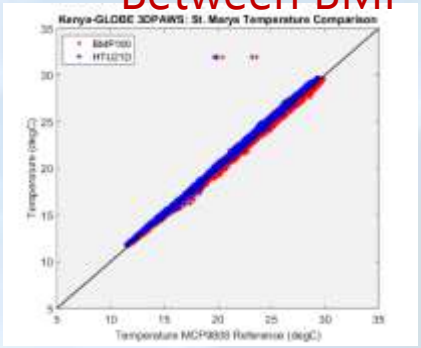
Evaluation of Observations at GLOBE Schools

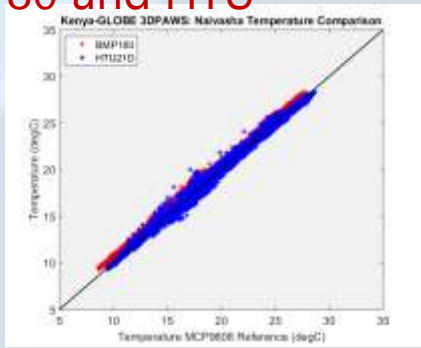
Inter-comparison of precipitation and temperature observations by 3D-PAWS installed in the GLOBE schools in Kenya

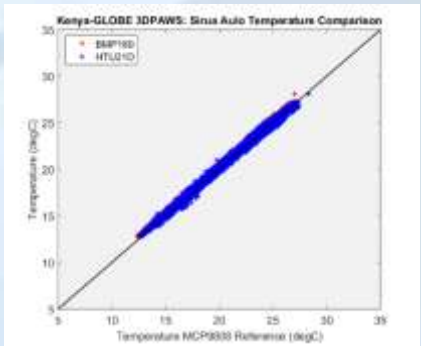
3D-PAWS and Manual Precipitation Gauge

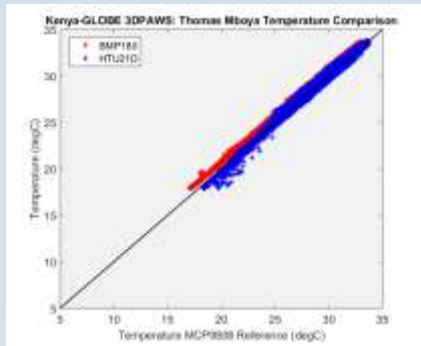


Temperature Sensor Inter-comparison
Between BMP180 and HTU









3D-PAWS Open Data Access

Data stored locally at each station

- 2+ years of data can be stored on local storage drive

Real-time Access:

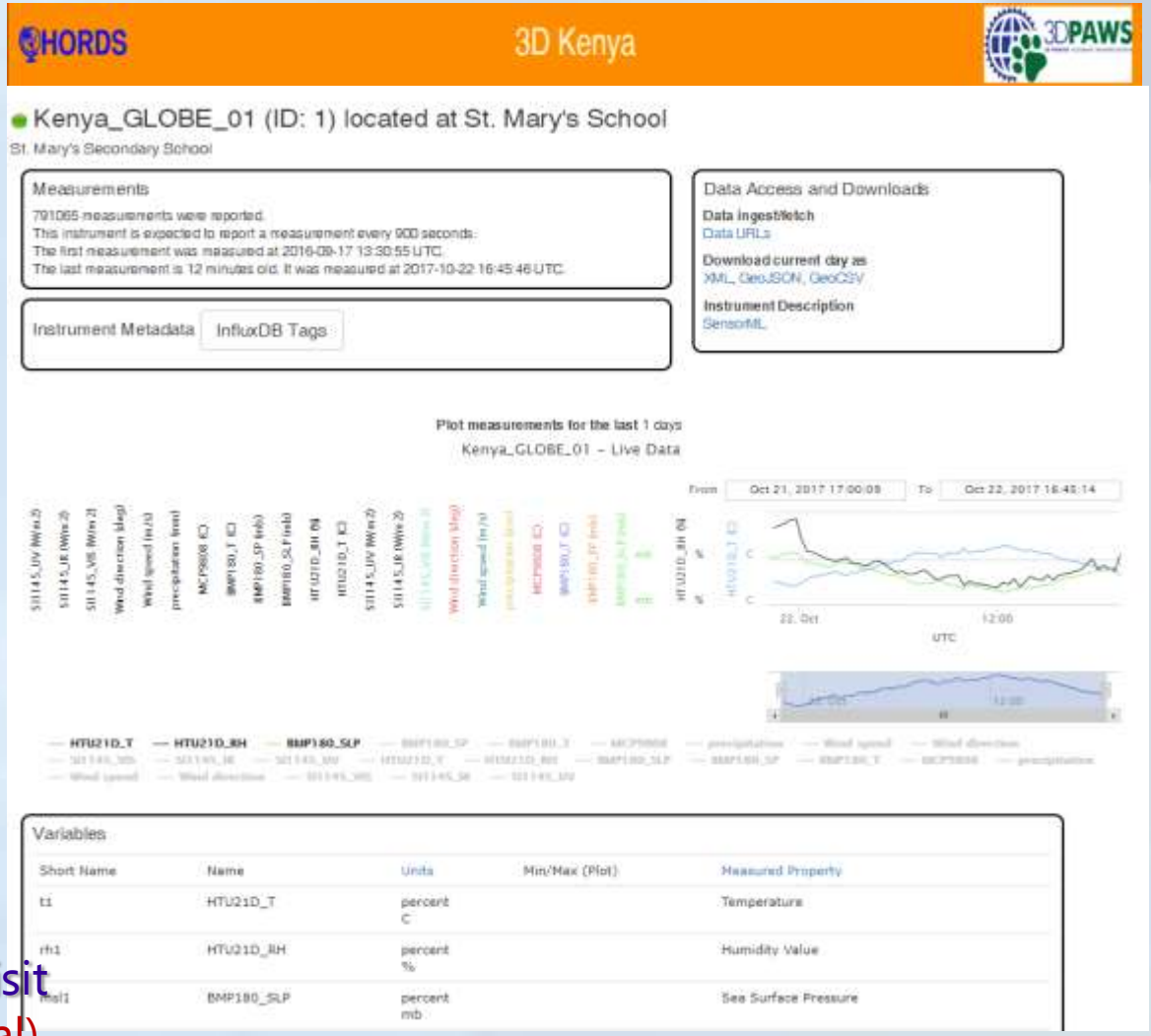
- Web-data services (CHORDS)
- Local HydroMet Office climate data services
- GLOBE and other network data services

Data currently hosted by:

CHORDS (**C**loud-**H**osted **R**eal-time **D**ata **S**ervices for Geoscience) data portal

To access and visualize data, visit

- http://3d.chordsrt.com (Global)
- http://3d-kenya.chordsrt.com (Kenya)



Visualization of 3D-PAWS Data Portal (Kenya)

3D-Printed Automated Weather Station (PAWS)

Component	Estimated Cost (USD) -
Initial setup cost for each local network	$5000+ 3D-printers, tools, supplies (wires, connectors, solder)
Mounting Components (pipes, brackets, guy wires)	$100/site
Raspberry Pi and power cable	$60/site
Micro-sensors for temperature, pressure, humidity, wind, and precipitation	$100/site
3D Printed Plastic filament for instrument housing	$60/site
Power	Commercial Power: minimal cost Solar power/battery system: $50/site
Communications	Wireless USB: minimal cost Cell Modem: $30/site* Satellite Modem: $50/site*(alternative)

+Recommend purchasing two to three 3D printers to provide additional printing capability and backup resources

*The cost doesn't include the monthly or yearly service costs.

3D-Printed Automated Weather Station (PAWS)

Planned New Sensor Development	Time Frame
Soil Moisture/Temperature	Late 2017
Lightning Detection	Late 2017
Stream/water flow gauging	Early 2018
Air Quality (Ozone, PM2.5), etc.	Early 2018
Heated Precipitation Gauge	Mid 2018

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Application Development

- **Applications using weather station observations:**
  - **Weather forecasting**
  - **Early Warning Systems**
    - **Flash flooding**
    - **Severe weather**
  - **Making engineering decisions**
    - **Water resource management**
    - **Agriculture**

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