3D-PAWS IoTwx

iotwx.github.io

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History of Weather Observing

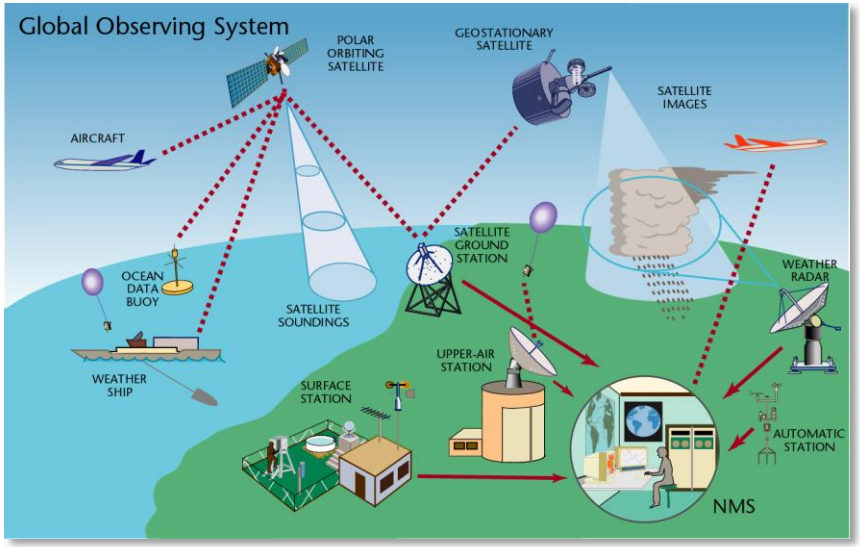
- Since the earliest times of civilization (Egyptian, Greco-Roman, etc.), we have been interested in weather observing (for planning, prediction, agriculture, etc.)
- **Qualitative** measurements dominated prior to 1500
- The **Scientific Revolution** brought new tools to bear on measurement (barometric pressure, quantitative temperature and humidity, etc.)

- **Longest running weather observation records in UK**: Green Templeton College 204 years continuous daily weather records

- **Longest running weather station in US:** Blue Hill Observatory (near Boston) -- continuous operation since 1885

Today, weather sensing is everywhere …

- In the US alone, thousands of **surface stations** and hundreds of **radiosonde** observation platforms continuously gather data
- Weather **satellites** capture **thousands of continuous measurements** to support forecasting, warning and disaster assessment
- **Radar** capture continuous valuable data for forecasting and modeling
- Computational **modeling and forecasting is** central



Source: WMO

- Data **collection** is now **at a scale** and **quality unimaginable** in the 1800s

… and now there are DIY sensing with 3D printers

3D PAWS

A LOW-COST, PROFESSIONAL GRADE 3D PRINTED WEATHER STATION

Major Deployments Internationally

- USAID, WMO, country supported projects (Kenya, Namibia)
- Lake Victoria - 20 stations
- 11 CHORDS portals with over three dozen stations
- Some stations operating for over 2 years

Designed for standard suite of automated meteorological measurements

- Radiation shield (T,P,RH), Anemometer (WS), Wind Vane (WD), Rain (Precip), Light

Raspberry Pi-based, commonly available sensor and design technologies

- All parts can be found easily through online vendors

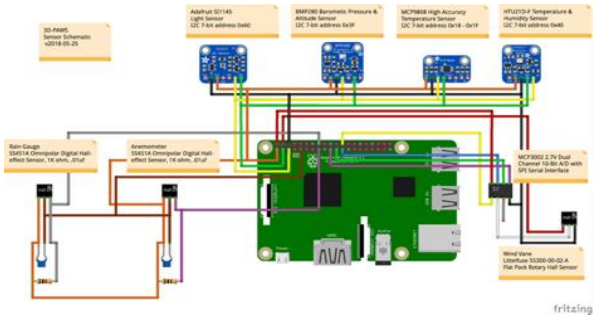
Supports long term field deployments with self-sustaining power and 3d-printed field replaceable parts

- 20W solar panel and rechargeable battery connected by centralized cabling system
- Advanced engineering design with replaceable, custom 3d printable component and connectors

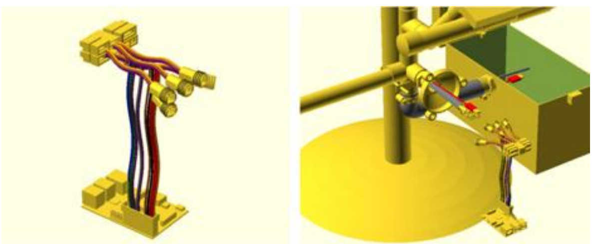
Uses open source data portal for standards-based measurement data storage

- Integration with CHORDS portal for data visualization and graphing

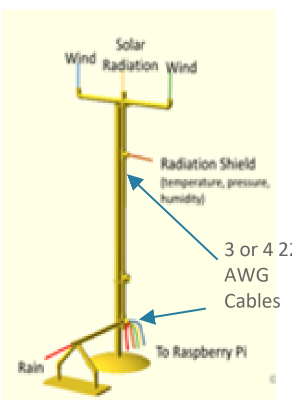
3D PAWS HARDWARE PARADIGM



All Sensors interconnected to a Single Raspberry Pi



A network of wires connect sensors via 'Common Rail' system



Build and deploy

- all dependencies and complexities at build time
- adding new sensors or modules post-build can be challenging
- hardware designed for stability

Central power allows wires to connect to one central power system

- all-or-none power paradigm with common rail system
- durable 22AWG cables provide longevity
- continuous charging with solar panel, but high capacity battery provides >108h of power before recharge required

Electronic parts are available through online vendors, remaining parts are locally available or 3d printed

- frame parts can be commonly found in most hardware stores
- field-replaceable parts can be printed reducing time and cost to repair

3D PAWS SOFTWARE AND DATA PARADIGM

Raspbian

python

CHORDS

Open Source Software

- all software is based on open source, non-proprietary tools and technologies
- python
- Raspian OS
- CHORDS (EarthCube/NCAR EOL) portal is open source

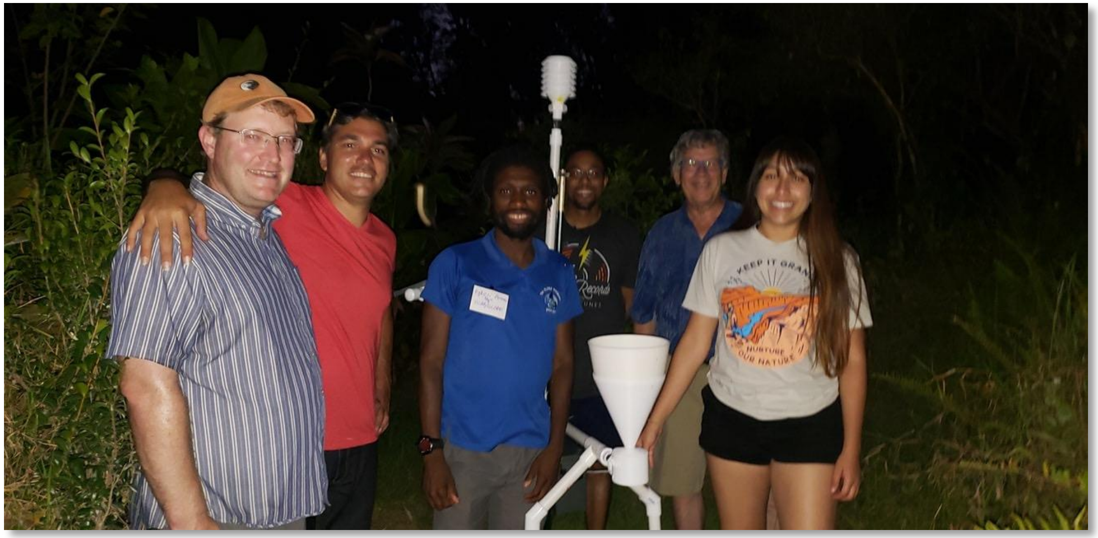
Data is open and freely available via CHORDS portal

- all data continuously available online
- data accessible via Web API
- custom visualization capabilities
- data can be archived and permanently stored (e.g. https://doi.org/10.6084/m9.figshare.7707518.v2)

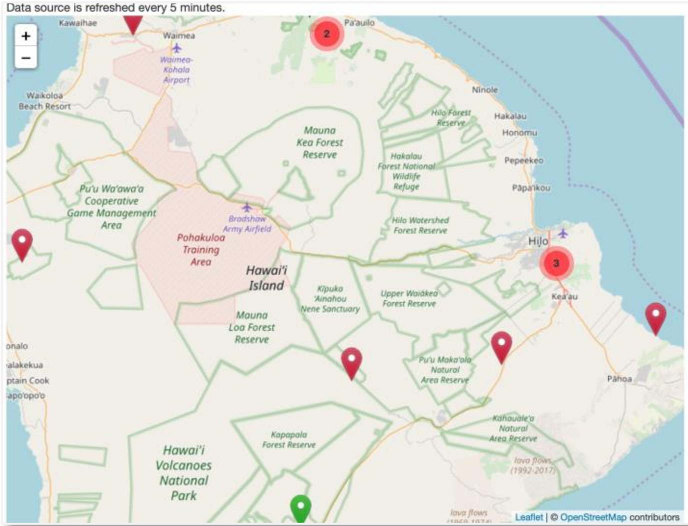
Fully replaceable/hackable code based

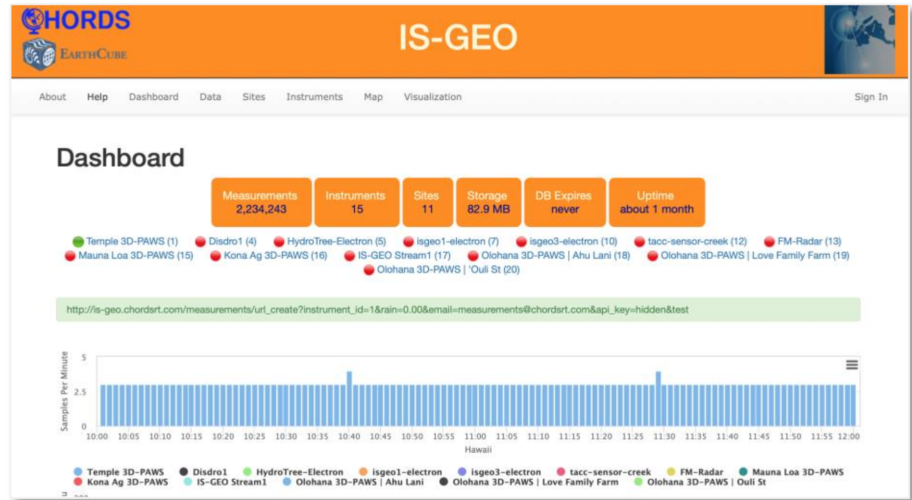
- all software can be replaced, updated, customized …

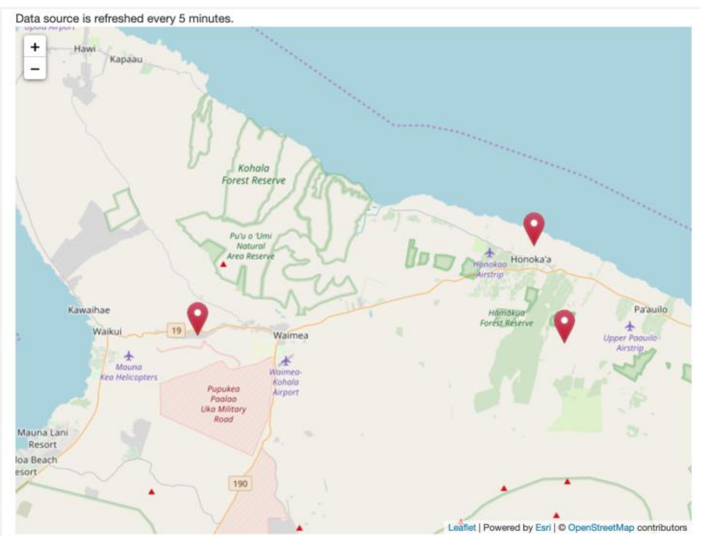
IS-GEO 2018 Deployment

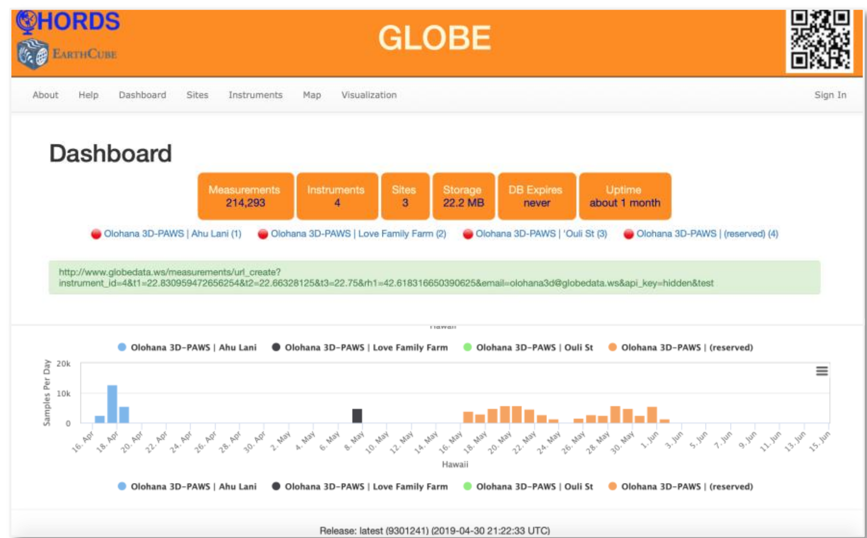


3D PAWS HAWAII DEPLOYMENTS – 2018+2019



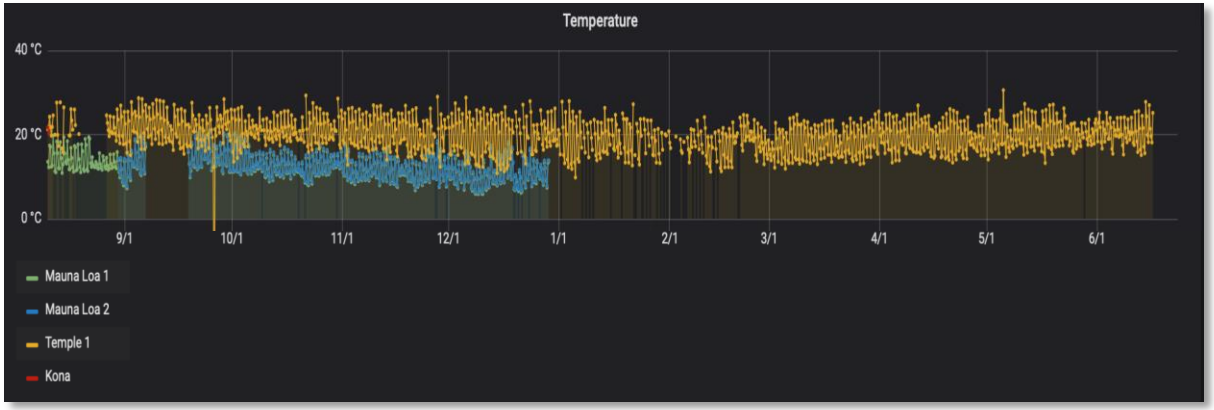






3D PAWS DATA SUMMARY AND LEARNINGS

- **>2M data points in 2 stations**
  - 10 months (Temple)
  - Hurricane Lane data (Mauna Loa)
  - http://doi.org/c7cn
- **Large continuous dataset of temperature, humidity and pressure**
  - precipitation data quality still under review for calibration concerns
- **Power stability exceeded expectations**
  - solar panels and battery health remained strong through the 10 months
- **Communication stability**
  - remote stations connected to wifi may require re-authentication and communication maintenance



DEPLOYMENT LEARNINGS AND FEEDBACK

HARDWARE

- steep learning curve requires printing, soldering and wiring skills
- communications and data uplink
- large number of 3d printed and other parts requires management
- common rail interconnected sensors introduce diagnostic challenges

SOFTWARE

- no centralized configuration or change management
- one instrument's code may vary from another and updates are not easily managed
- scalability of software systems not mature – most deployments are "one-off" and software can be brittle

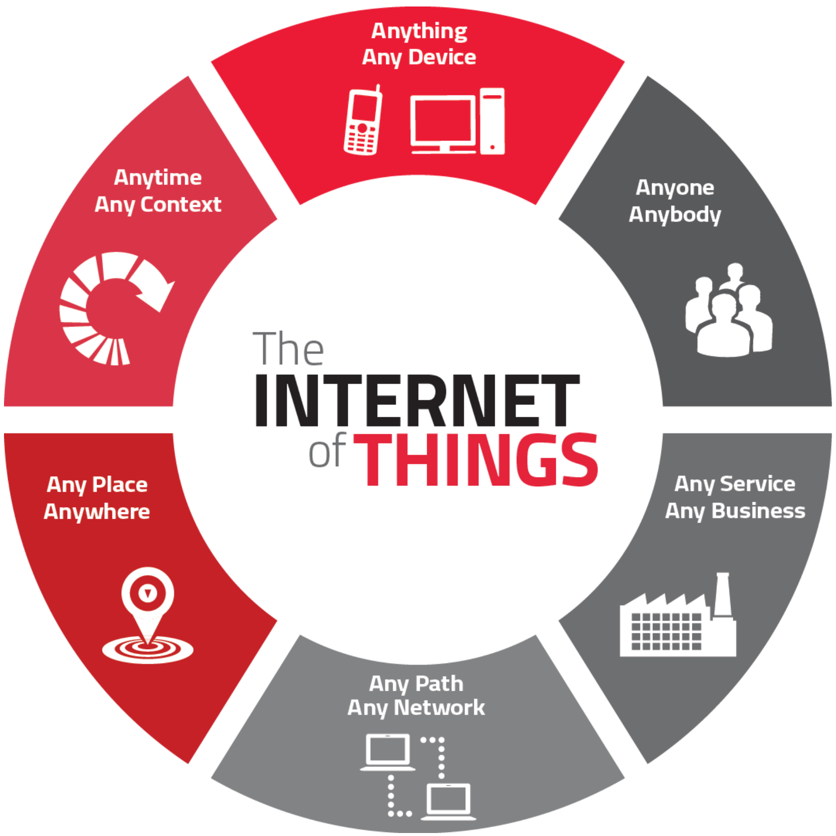
DATA AND MONITORING

- improved remote management (ngrok, hot spot networks, etc.)
- ability to automatically connect with CHORDS or GLOBE databases
- large-scale data archive and data availability

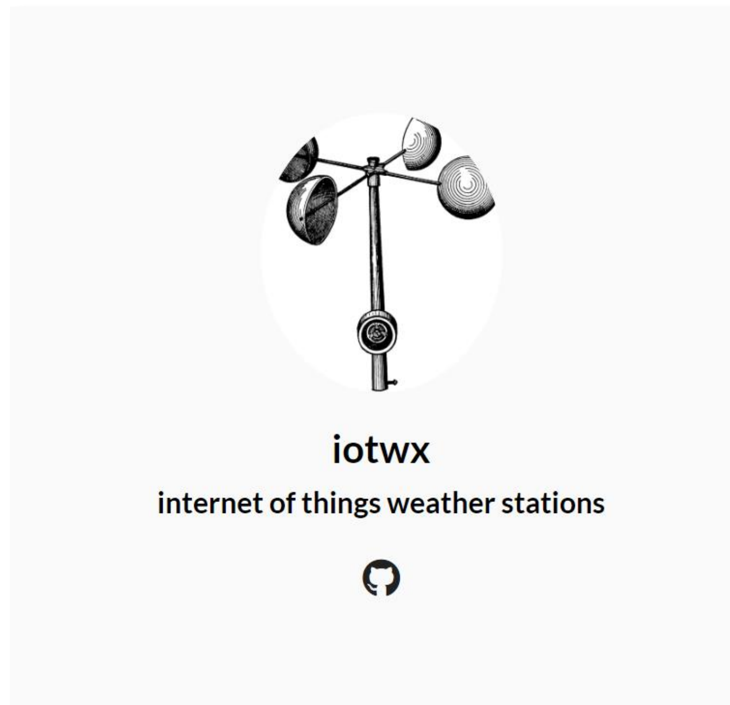
These areas of improvement inspired us to conceive an IoT based system

IoT?

INTERNET OF THINGS
A PARADIGM READY FOR WEATHER SENSING

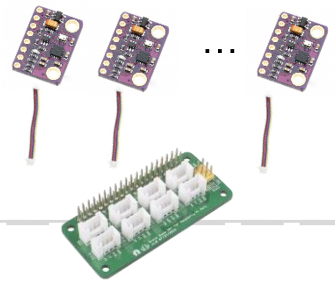


Source: https://iotworm.com/biggest-challenges-for-the-internet-of-things/

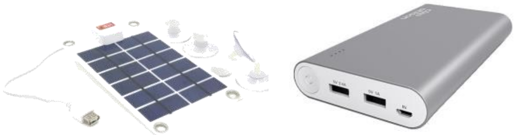


https://Iotwx.github.io

NODE-BASED IoTwx SYSTEM PROPOSAL

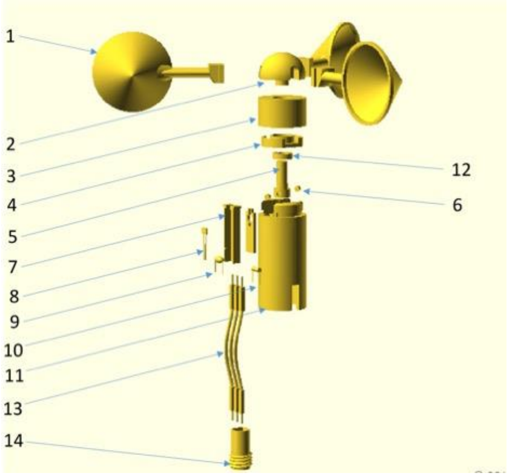


	1-4+ sensors (Grove)	$10-50
	Grove HAT	$10
	Pi Zero WH	$15
	20000mAh USB Power Bank + 10W USB Solar Panel	$30



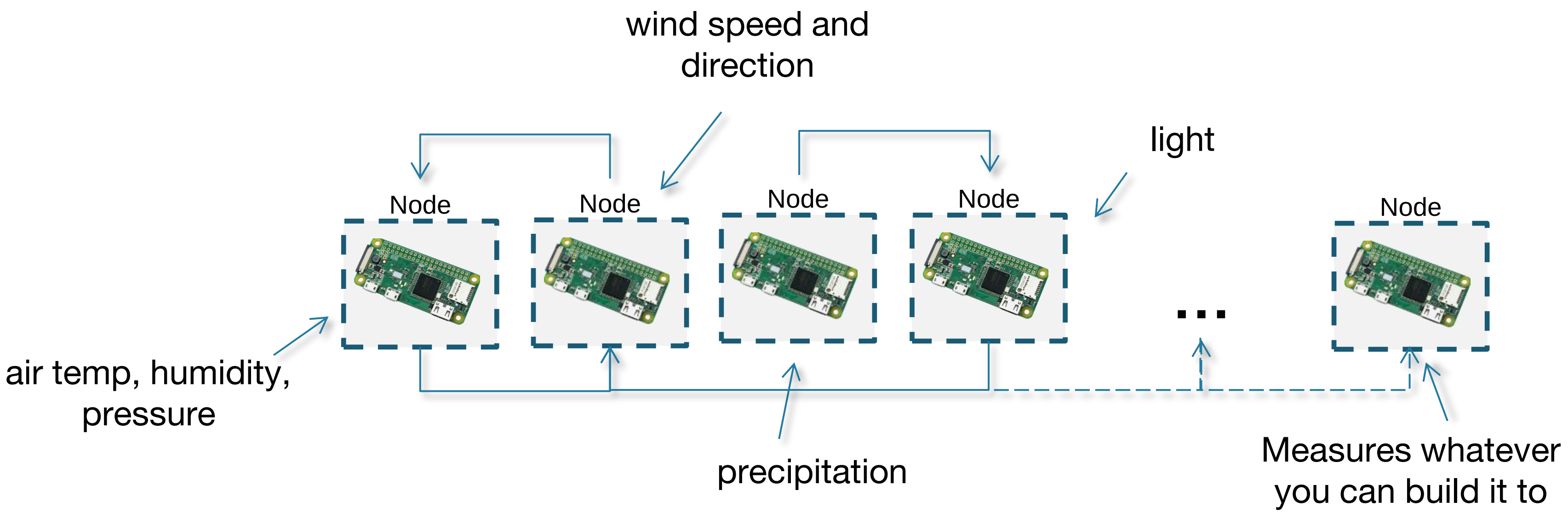
$55
(Node without sensors)

3D-Printed Node Housing Example (Anemometer)



$15-30
(depending on print configuration)

A “STATION” IS JUST A COLLECTION OF IoTwx NODES



- Disaggregated nodes distribute failure points
- Nodes can perform simple or complex measurements
- Underlying function and role of each node can be flexibly managed
- Inter-node communication can facilitate IoT architectures by exploiting a variety of communication protocols (Wifi, LoRA, BLE, Zigbee, X-Bee, WeMo, etc.)

IoTwx NODES CAN OPEN UP NEW USE CASES

Cost-effective stations for research project support

- support field projects by providing lower cost IoTwx solutions
- help field programs evaluate IoTwx based solution or direct them to larger scale solutions like NCAR EOL
- incorporate IoTwx into low-cost field programs and research:
  - low-cost station(s) in high altitude, Arctic, Antarctic or extreme conditions
- encourage new instrument design deployment and sharing

3d printed stations for K-12+ education and training

- support field deployments for community development and project based education
- integrate stations into classroom activities that meet Next Generation Science Standards (NGSS)
- support afterschool programs, maker spaces, and other educational applications
- collaborate with Minority Serving Institutions and Indigenous communities (i.e. Rising Voices and INCLUDES)

BUT WHY STOP WITH JUST THE STATION?

NODES CAN DO ANYTHING … RIGHT?

LIKE MAYBE RUN MODELS?

WRF AND MPAS MODEL DATA ASSIMILATION …

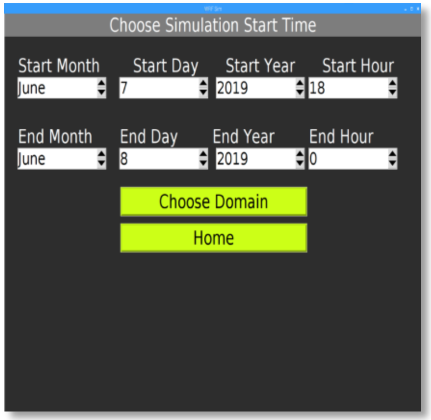
low-cost IoTwx might enable powerful new use cases

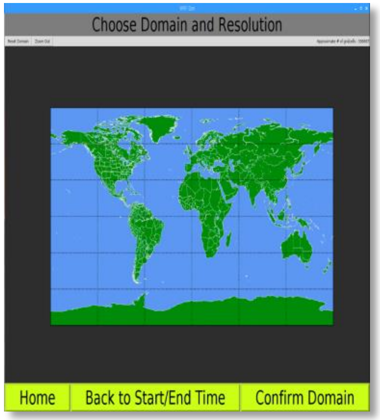
- Edge computing with WRF model may incorporate station observations
- Increased data points from stations allow researchers to explore micro-forecasting, data assimilation, and model initialization

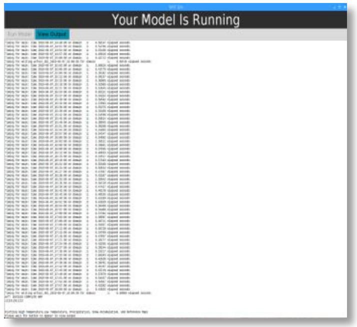
EDGE COMPUTING NODE WITH WRF MODELING

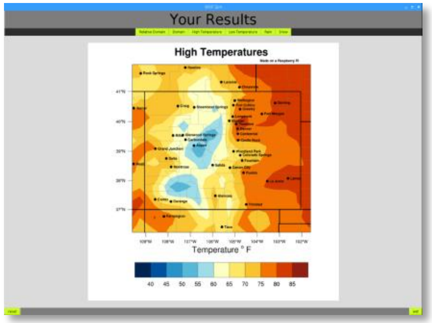
WRF on a Raspberry Pi?

- Supercomputer simulation with Raspberry Pi Cluster
  - runs full weather model
  - user friendly
  - runs in parallel to fully simulate operational machine cluster
  - modifiable and extensible
  - Can run on single Pi compute node









IOTWX STATION METRICS, DURABILITY AND STABILITY

- **HARDWARE**
  - long-term durability of 3D printed station housings, connectors, and other parts unknown – deployment in extreme conditions not known
  - power consumption, storage, and reliability needs investigation
  - time to deployment, assembly, and repair needs benchmarking
- **SOFTWARE**
  - efficiency and speed of 3D PAWS code relative to compute cycles/usage
  - performance curve for edge computing (WRF) on Pi B+, Pi Zeros, NVIDIA Jetson Nano and TX2
- **DATA AND MONITORING**
  - benchmark accuracy and reliability of Grove, Qwiic and other sensor options
  - metrics on data stream reliability and archiving workflow

CONCLUSIONS

- **MODULARITY**: node-based weather station might be a cost effective platform for flexible real time environmental data collection
- **EDGE COMPUTING**: explore edge computing (e.g. micro-forecasts, early warning systems, etc.) where WRF modeling and observation live together
- **COST**: low station costs enables increased data collection resolution while supplementing more expensive or advanced platforms
- **EDUCATION:** NGSS-based educational tool with a series of in class activities and teacher tools allows students to learn about weather forecasts from observation, hardware, software, forecasting, and broadcasting

THANK YOU!

LET'S PLAY

- Agbeli Ameko
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