05 September 2015

A 3D Printed Weather Station

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NCAR/Research Applications Laboratory and UCAR/JOSS

Vision – Kelly Sponberg

- **Kelly had a vision to provide access to weather and forecasting information to remote regions of the world**
- **In many developing countries, access to information has been limited because of the high cost of weather systems**
- **His idea was to develop low-cost weather stations that Meteo services could make sustainable – 3D printed weather station**
- **Unfortunately, Kelly passed away in August, but we are continuing with his vision in memory of him**

Project Background

- **Since 1997, USAID's Office of U.S. Foreign Disaster Assistance (OFDA) has been partnering with the NOAA and UCAR to find an affordable way to help developing countries monitor, predict and prepare for high-impact weather**
  - Pursing technology to improve weather observation networks and communication of information
- **Development of program called: RANET (Rural Communications using Radio and the Internet)**
  - Make weather, climate and related information accessible to communities in remote areas of Africa, Asia and Pacific
  - RANET partners with national meteorological services to provide weather information to rural communities
  - Access to weather information to prepare for adverse weather, and improve their livelihoods

Project Background - RANET

- **Developed partnerships in Africa and the Pacific since 2006**
- **Local ownership within the program and through equipment deployment**
  - Sustainable networks – low cost, reliable – development of 3D printed weather station
- **Work with partners to develop a grass-roots (e.g., at the farm-level) response to community information needs**
- **Technology implementation, not a platform, based program**

Project Background – Instrument Design

- **Deployment of commercial automatic weather stations limited**
  - High cost provides only limited sampling
  - Maintenance problems
- **Experience using lower cost commercial stations**
  - Performance marginal
  - Parts become obsolete
- **Vision**
  - Low cost 3D printers start to evolve in 2012
  - A large variety of low cost electronic sensors are available
  - Why not design a system that can be manufactured locally?
- **Goal**
  - Design a low-cost reliable 3D weather station that can be manufactured and deployed at a regional Meteo Office – take ownership of their own automatic weather stations

1st Deployment – Zambia Pilot Project

- **The initial deployment of the 3D printed weather station network will focus on Zambia over a 3-5 year period**
- **Project Goals:**
  - Develop and implement GIS network design tools
  - Conduct a site survey and select optimal sites
  - Develop and implement the network of surface sites using low-cost, reliable 3D printer weather stations
  - Developing a database system for storage, dissemination and display of surface observations
  - Training on how to build and maintain an end-to-end surface network system
  - Integration of weather information decision support systems

Initial 3D Printed Weather Station Setup

- **3D printed housing components**
- **Low-cost sensors integrated into the weather station**
  - Temperature
  - Surface Pressure
  - Relative Humidity
  - Wind speed and direction
  - Precipitation

- **Raspberry PI Single Board Computer for data acquisition, data archiving, and communications**
- **Use locally made materials for site configuration**
- **Open source code (python and cshell-scripts) for communicating with sensors and to remote locations**
- **Wireless communications to central system (still in development)**

3D Printed Weather Station Sensors

- **Current Configuration being tested at the NCAR Marshall Research Facility with standard reference sensors**

Raspberry Pi

Wind Speed

Wind Direction

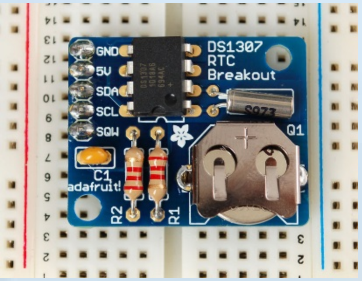
Weighing Precipitation Gauge

3D Printer Weather Station Sensors

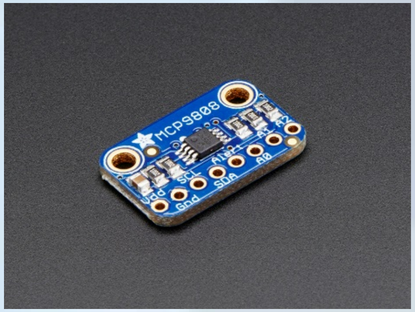
Temperature, Pressure, Relative Humidity

Current Configuration

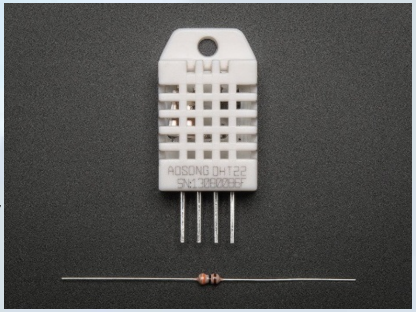
DS1307 – RTC



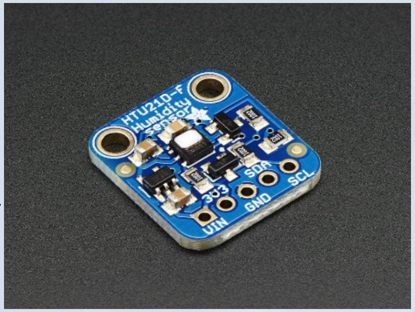
MCP9808 – Temperature



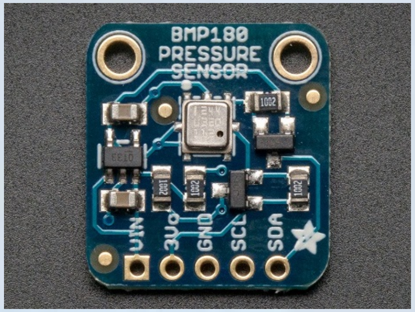
DHT22 – Temperature and Relative Humidity



HTU21D – Temperature and Relative Humidity



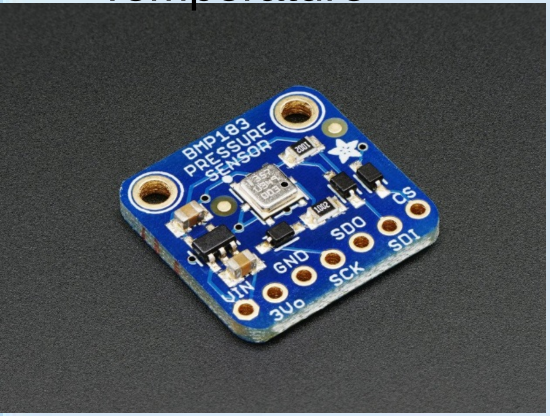
BMP180 – Temperature, Pressure, and Altitude



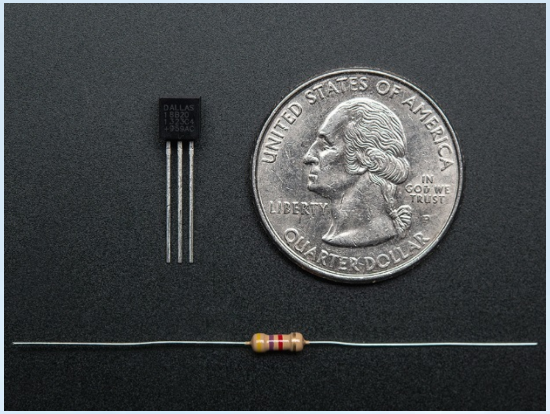
3D Printer Weather Station Sensors

Other Sensors Tested

BMP183: Pressure Temperature



DS18B20: Temperature

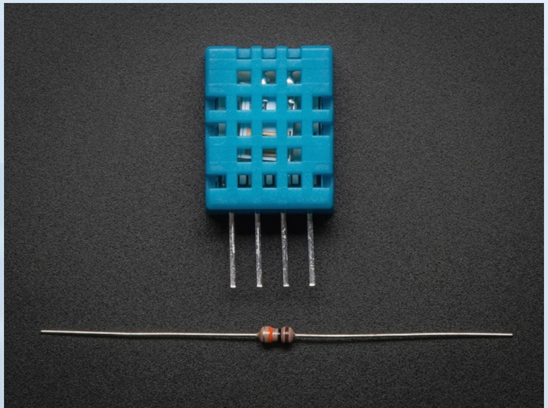


Other Possible Sensors

- Precipitation – tipping bucket
- Soil Moisture
- Radiation
- Emissions
    - VOC
    - O3
    - NOX…

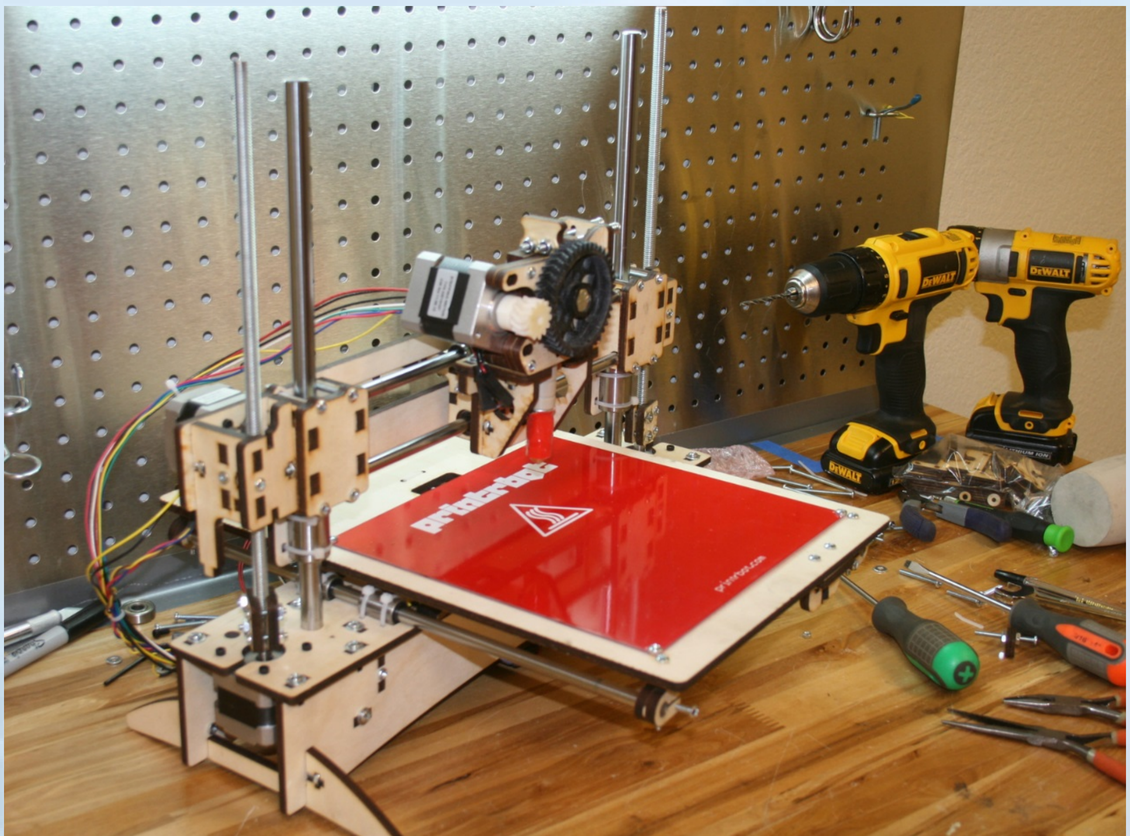
Camera: Cloud Fraction

DHT11: Temperature and Relative Humidity



Early Days

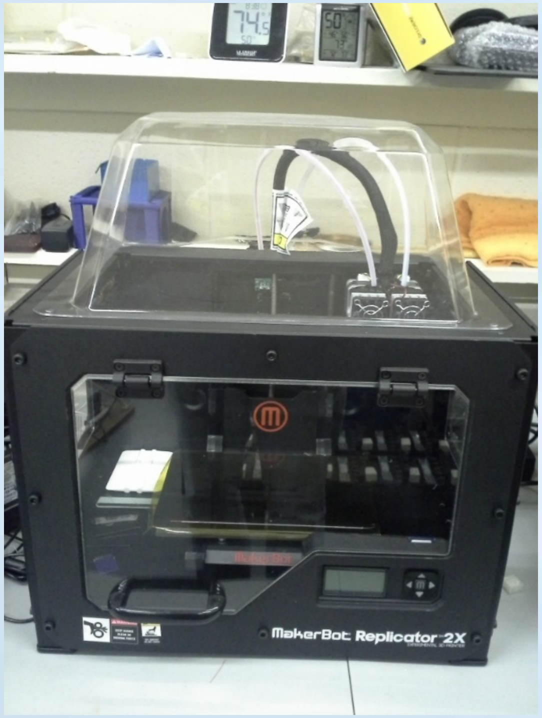
- **Received the first printer in December 2012 – a Printrbot Plus**



– PHOTO courtesy Tim Stark

Early Days

- **Tried some pre-assembled printers**



MakerBot Replicator 2X

Afinia H480

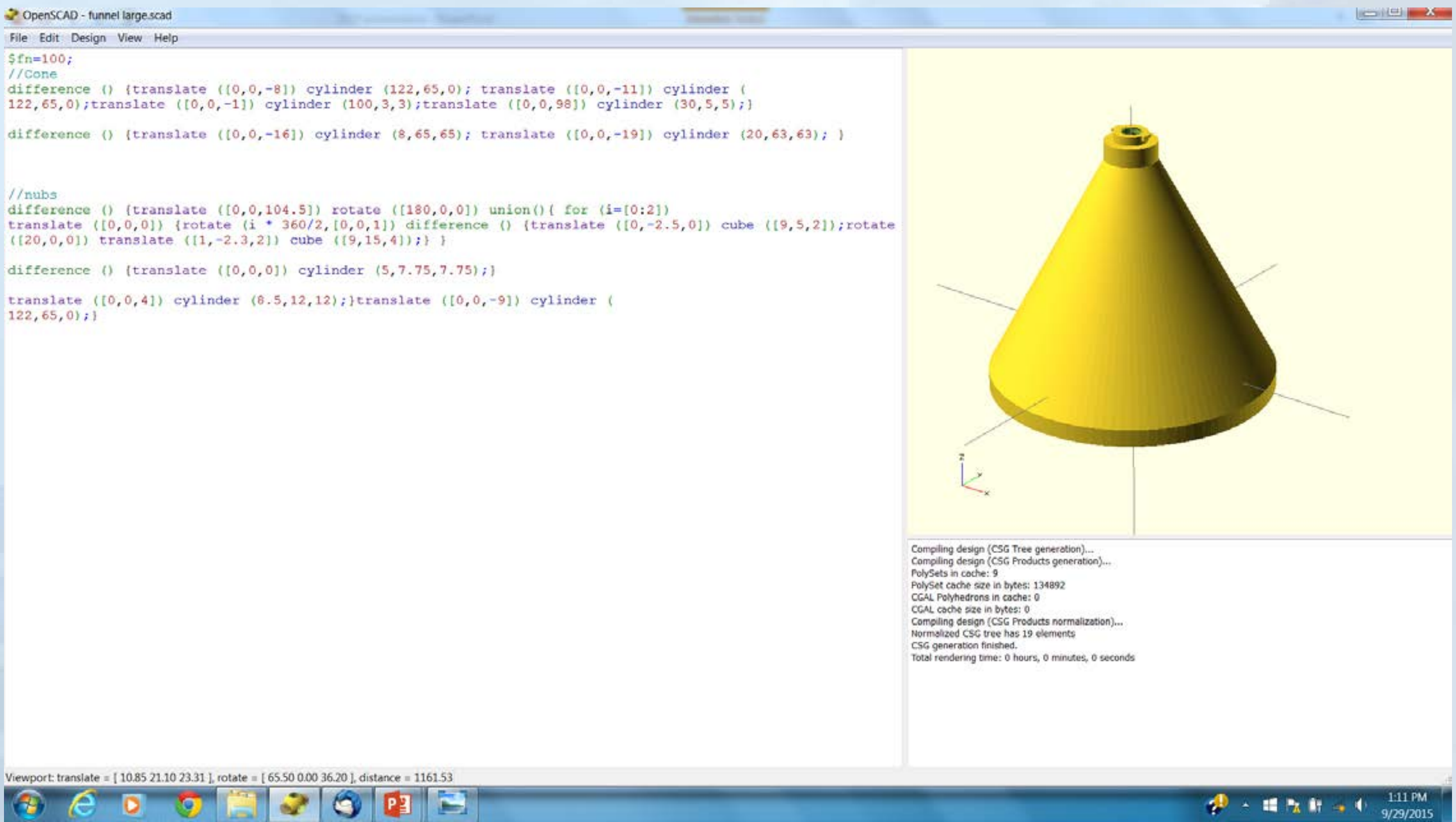
Latest

Afinia H800

Latest

Design

- **Open SCAD**
  - Free software; **http://www.openscad.org**
  - Like a 3D compiler that reads in a script file



Design

OpenSCAD - funnel large.scad

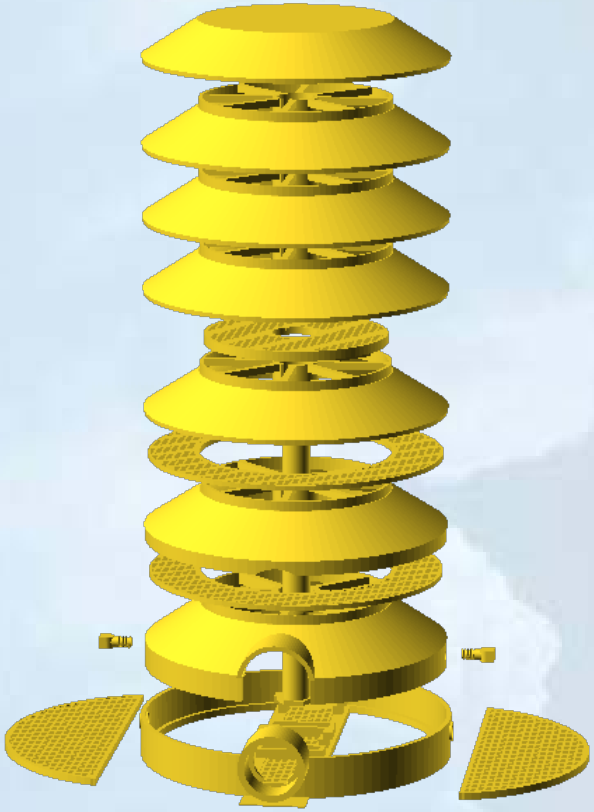
File Edit Design View Help

```
$fn=100;
//Cone
difference () {translate ([0,0,-8]) cylinder (122,65,0); translate ([0,0,-11]) cylinder (
122,65,0);translate ([0,0,-1]) cylinder (100,3,3);translate ([0,0,98]) cylinder (30,5,5);}

difference () {translate ([0,0,-16]) cylinder (8,65,65); translate ([0,0,-19]) cylinder (20,63,63); }



//nubs
difference () {translate ([0,0,104.5]) rotate ([180,0,0]) union(){ for (i=[0:2])
translate ([0,0,0]) {rotate (i * 360/2,[0,0,1]) difference () {translate ([0,-2.5,0]) cube ([9,5,2]);rotate
([20,0,0]) translate ([1,-2.3,2]) cube ([9,15,4]);} }

difference () {translate ([0,0,0]) cylinder (5,7.75,7.75);}

translate ([0,0,4]) cylinder (8.5,12,12);}translate ([0,0,-9]) cylinder (
122,65,0);}
```

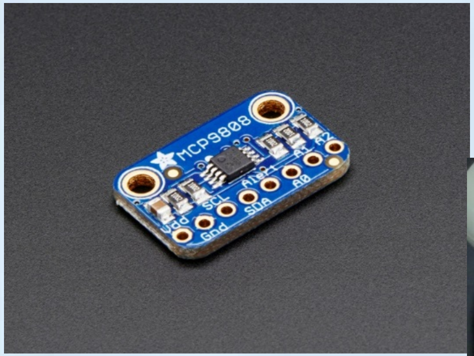
Materials

- **ABS**
  - Better Detail
  - Easier to clean up
- **PLA**
  - Tougher
  - Less prone to shrinking/warping
  - More likely to clog nozzles
- **Conductive**
  - Not noticeable
- **Soluble**
  - Early version not good
  - Water soluble PVA now available
  - Only useful with dual extruders

Radiation Shield

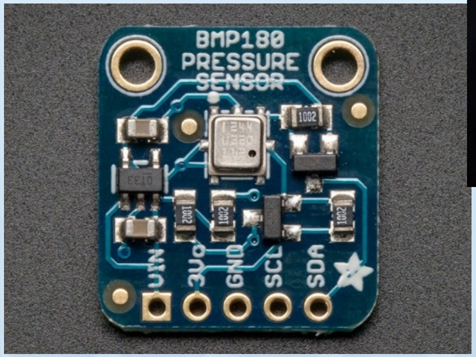


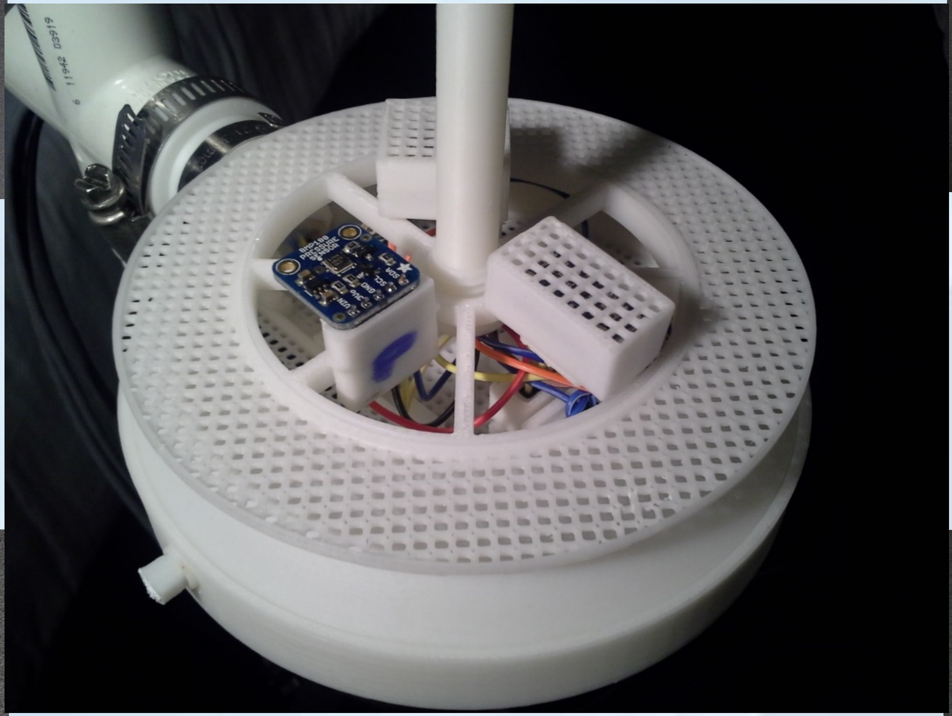
Radiation Shield

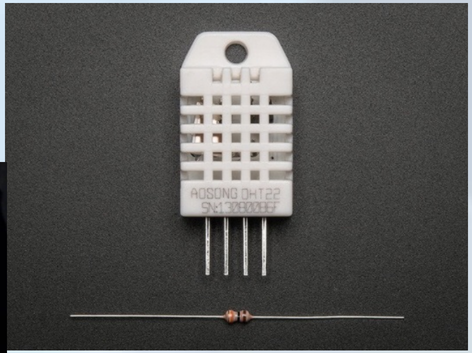


MCP9808 Temperature

BMP180 Temperature and Pressure

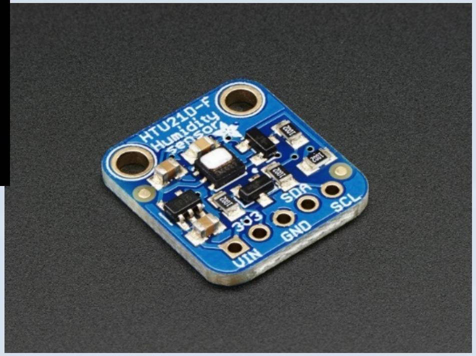






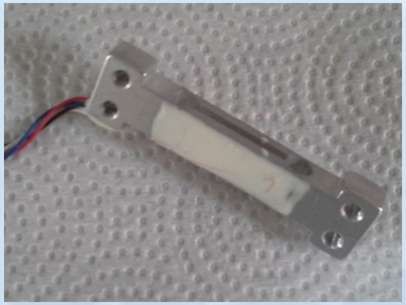
DHT22 Temperature and Humidity

HTU21D Temperature and Humidity

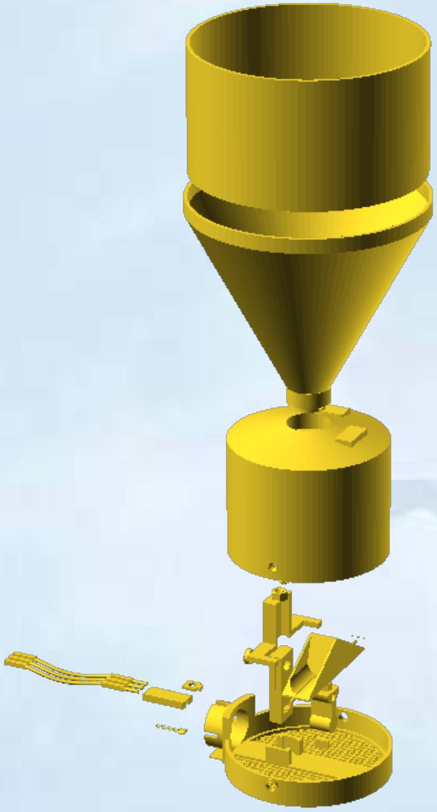


Rain Gauge - Hybrid

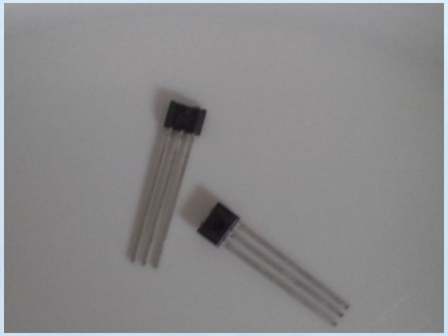
Amico Load Cell



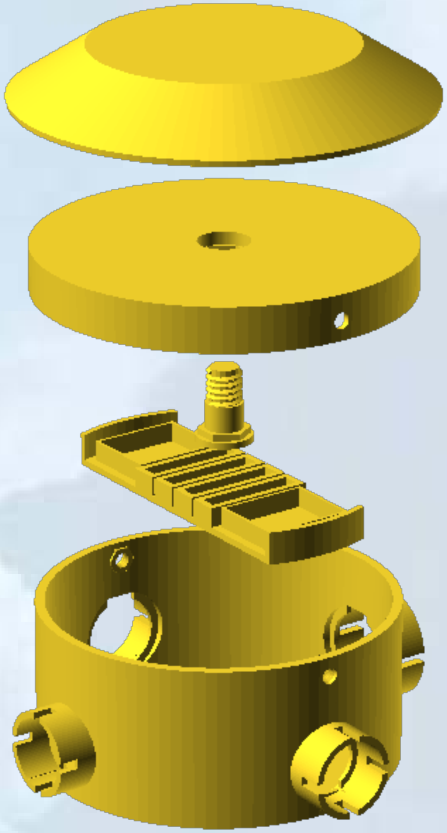
Rain Gauge – Regular Tipping Bucket



US1881EUA Hall Effect

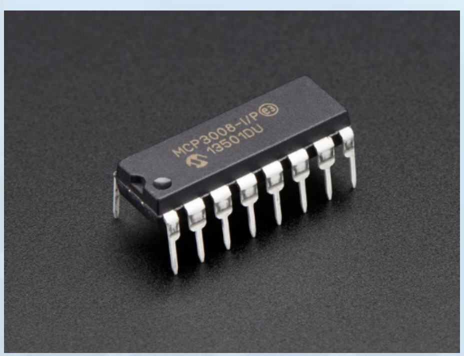


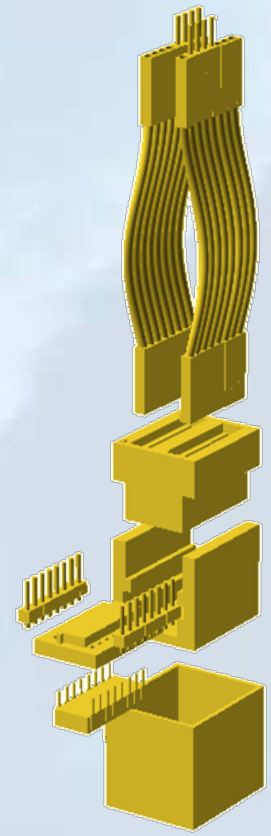
Junction Box



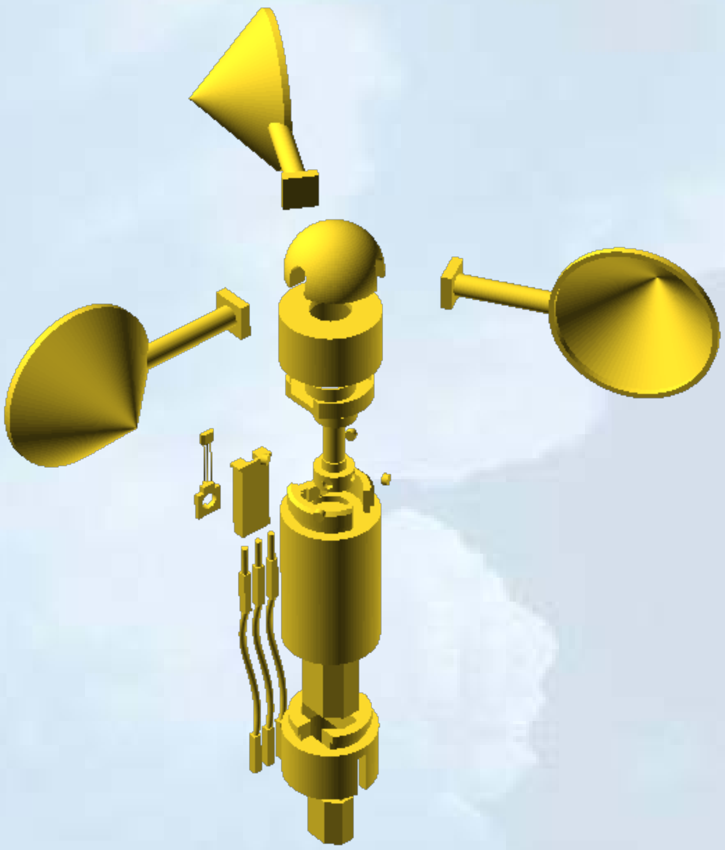
Push Fit Circuits

MCP3008 ADC

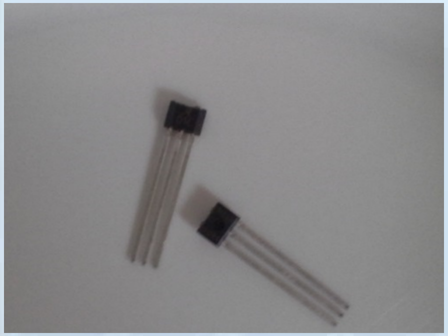




Anemometer



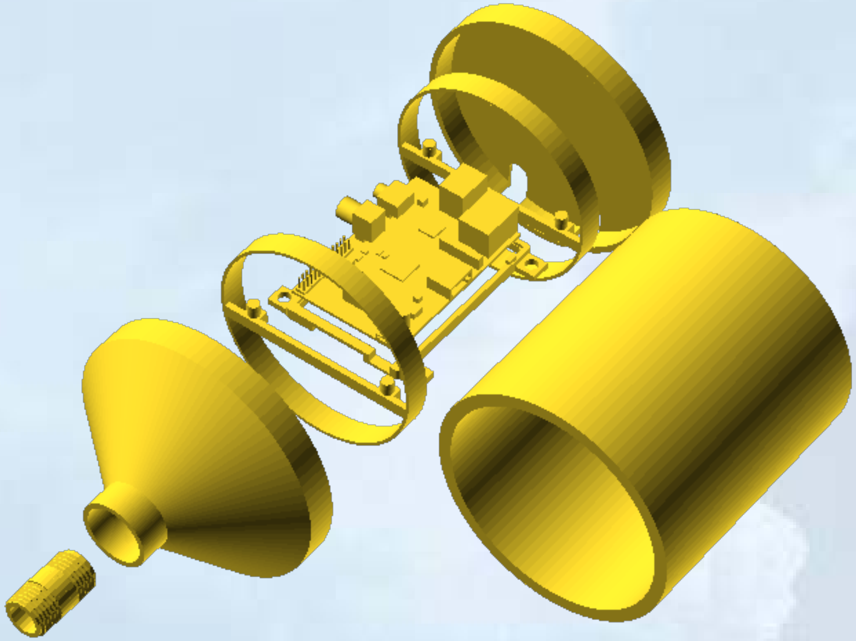
US1881EUA Hall Effect



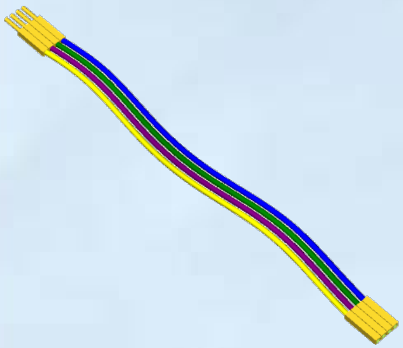
Wind Vane

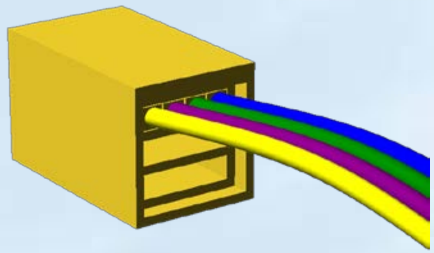
Hamlin 55300

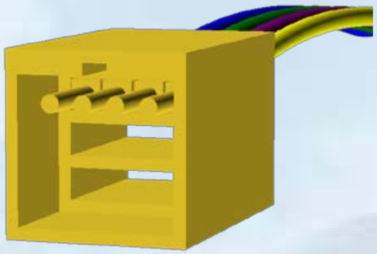
Computer Housing

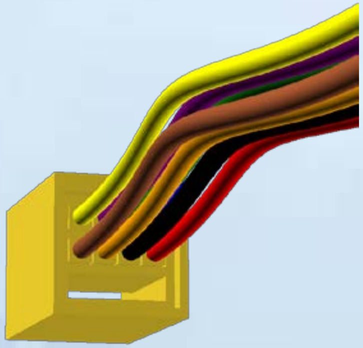


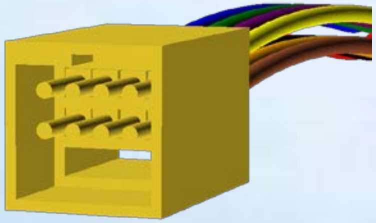
Connectors

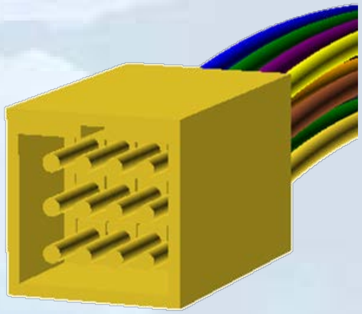


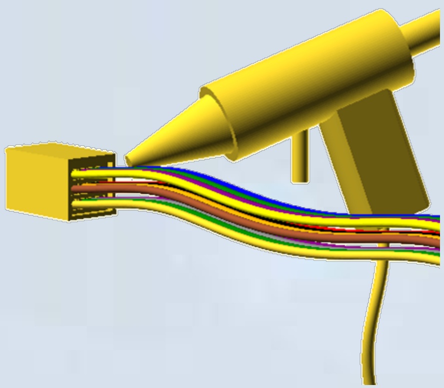










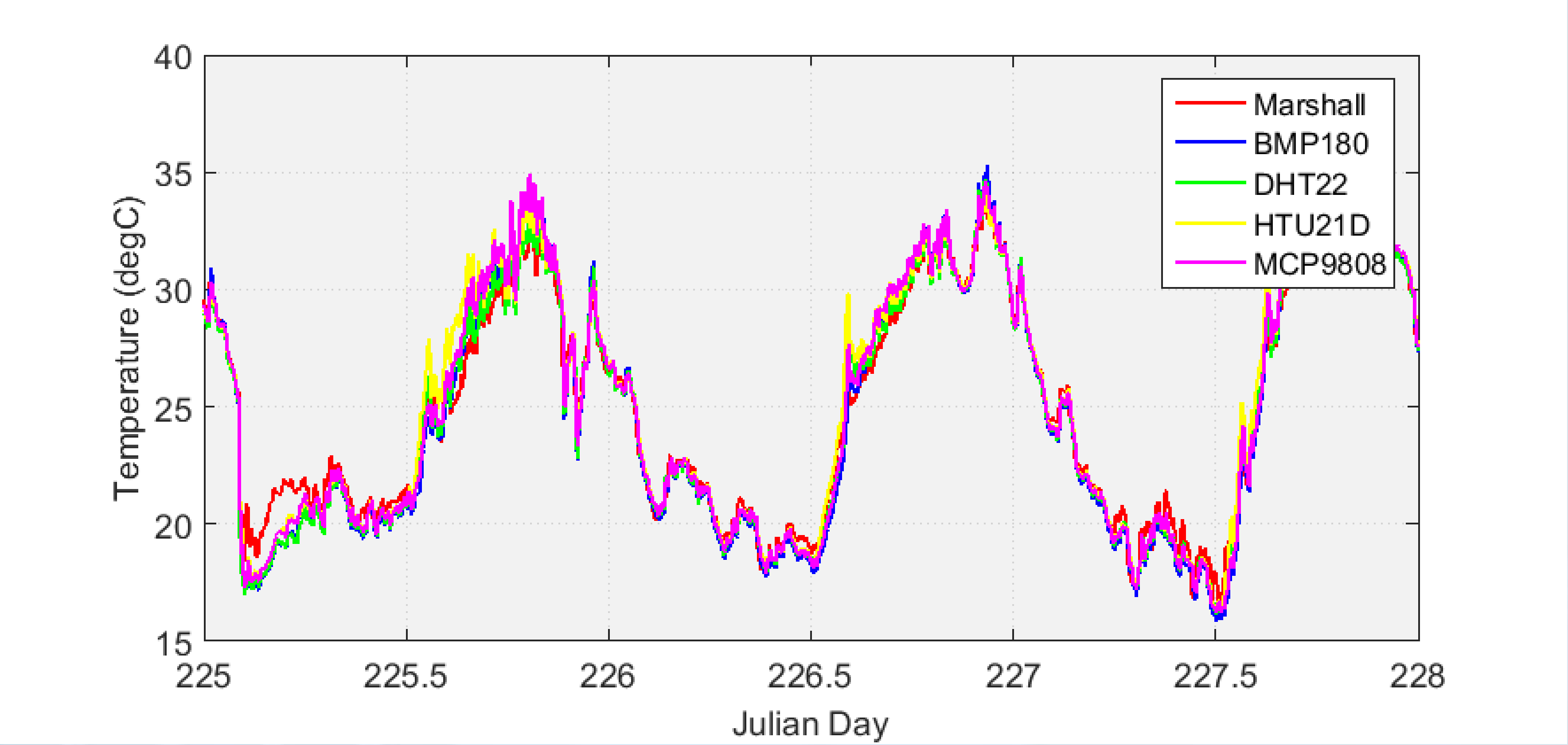


Cost

based on price per 100						
	Total		Plastic Parts		Weight (grams of plastic)	
Wind Direction	$15.31		7		40	
Wind Speed	$6.86		11		39	
Rain	$24.72		9		256	
Radiation Shield	$43.28		19		208	
Junction Box	$30.83		15		148	
Brain Box	$53.19		9		137	
Misc	$13.56					
Connectors	$3.54		40		55	
TOTAL	$191.29		110		883	grams

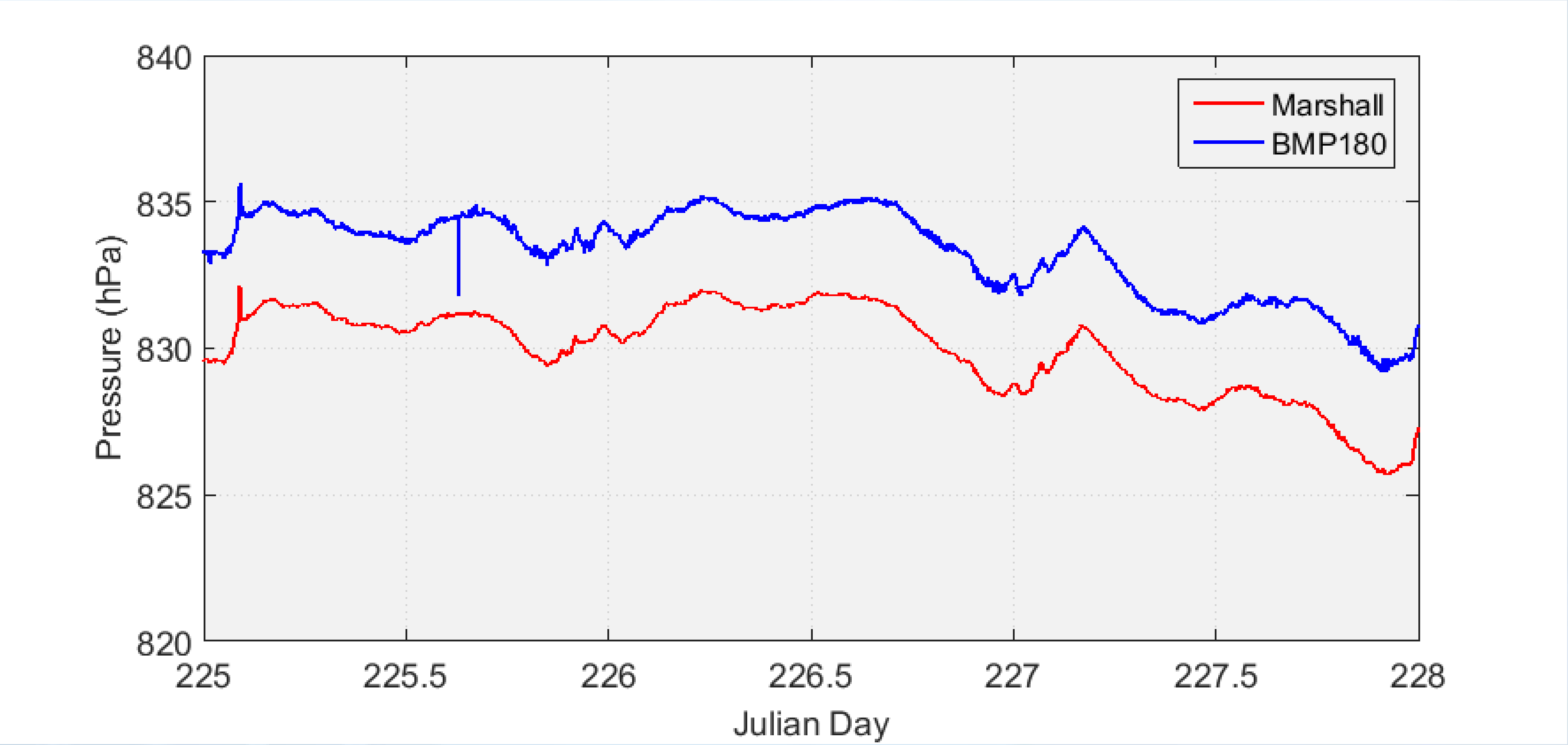
Data Evaluation

- **Temperature**



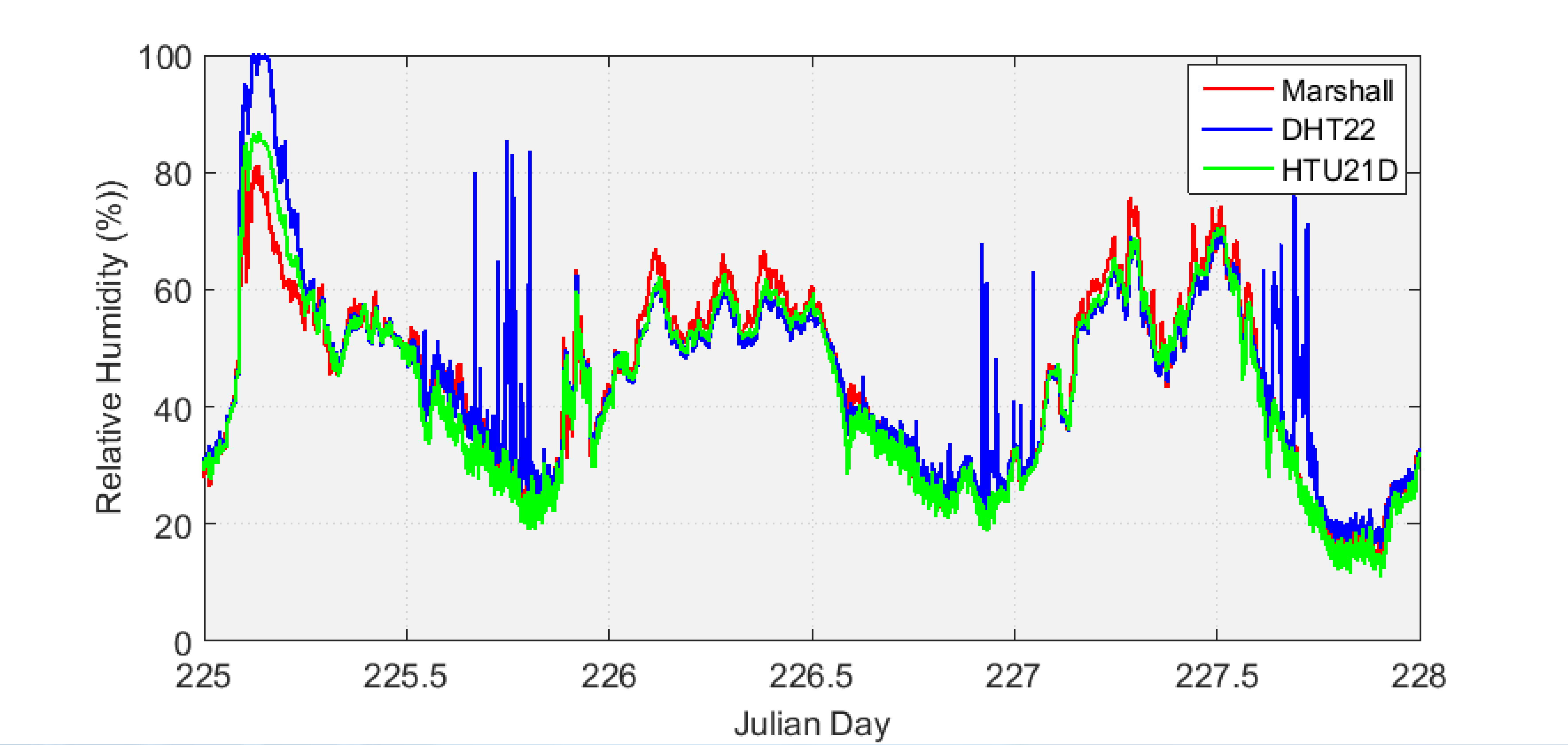
Data Evaluation

- **Pressure**



Data Evaluation

- **Relative Humidity**



Thank you