MINI-GNI

The Creation of a Sea-Salt Sampler with Arduino and 3D Printing Technologies

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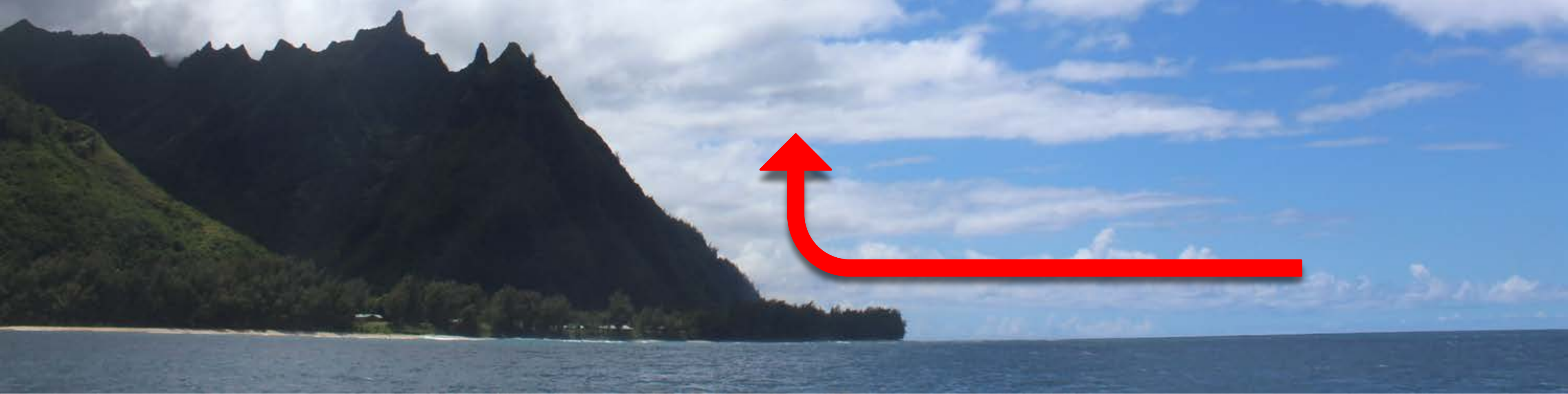
MOTIVATION

- Giant sea-salt aerosols are a known mechanism for rapid formation of warm rain
- Sea salt aerosols = Giant Cloud Condensation Nuclei (GCCN), 1-20 microns
- Cloud droplets formed on GCCN composed of sea-salt grow faster than other CCN (Jensen and Nugent, 2016)



PROBLEM

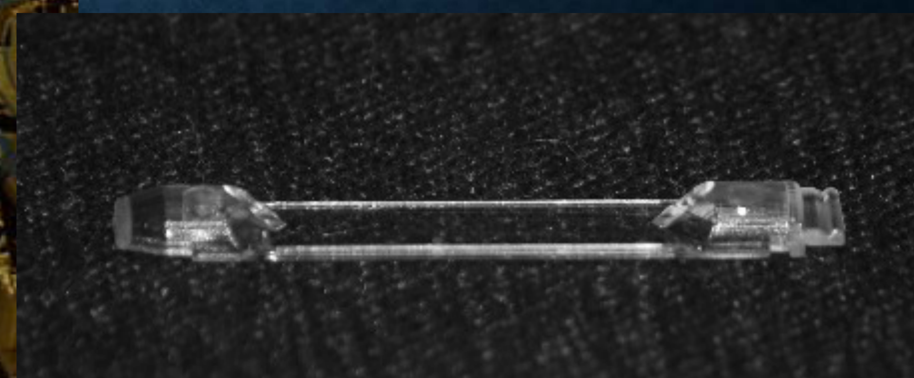
The GCCN size distribution is notoriously difficult to measure

- Optical probes that see small cloud droplets don't measure salt concentration or aerosol composition
- Aerosol probes are typically looking for much smaller particles
- GCCN (1-10 microns) sit right in the middle of the size range

The NCAR GNI slide impaction system.

Giant Nucleus Impactor

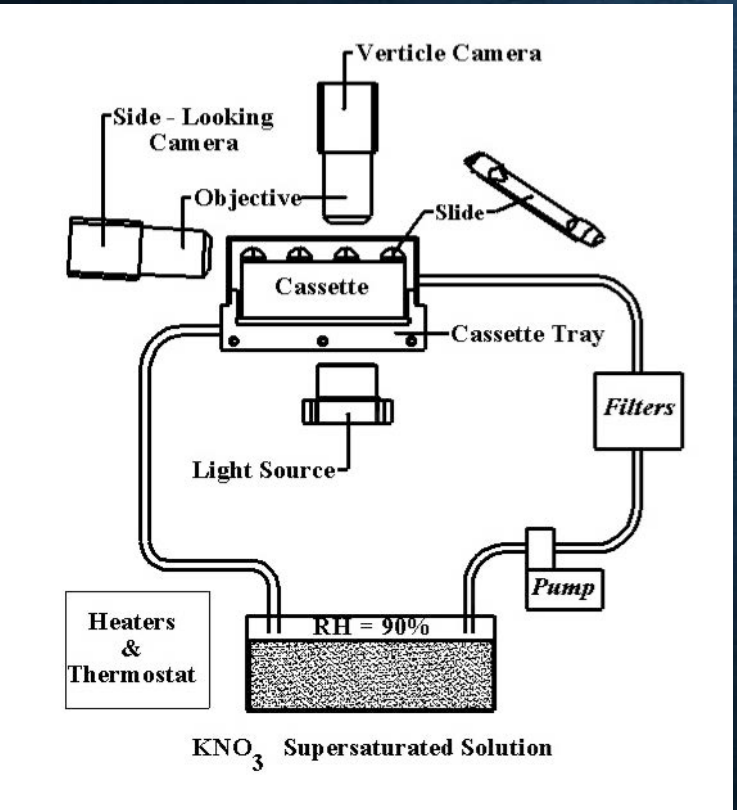
Polycarbonate slides are exposed to the free airstream and sea-salt aerosols impact onto the slide

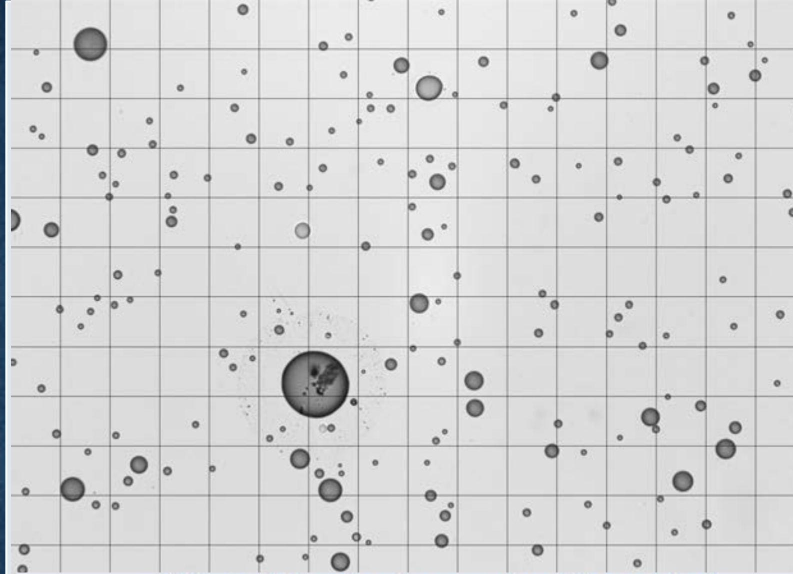


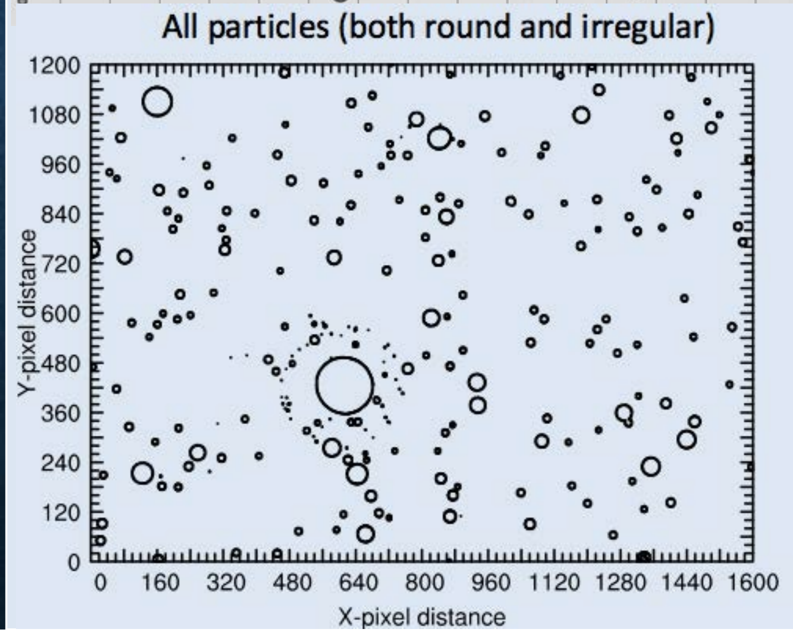
Optical microscope and image analysis:

Automatic digital microscopy, in a temperature-controlled cabinet.

Slides are kept in humidified air (90% RH), and sea-salt particles deliquesce to form spherical cap drops.

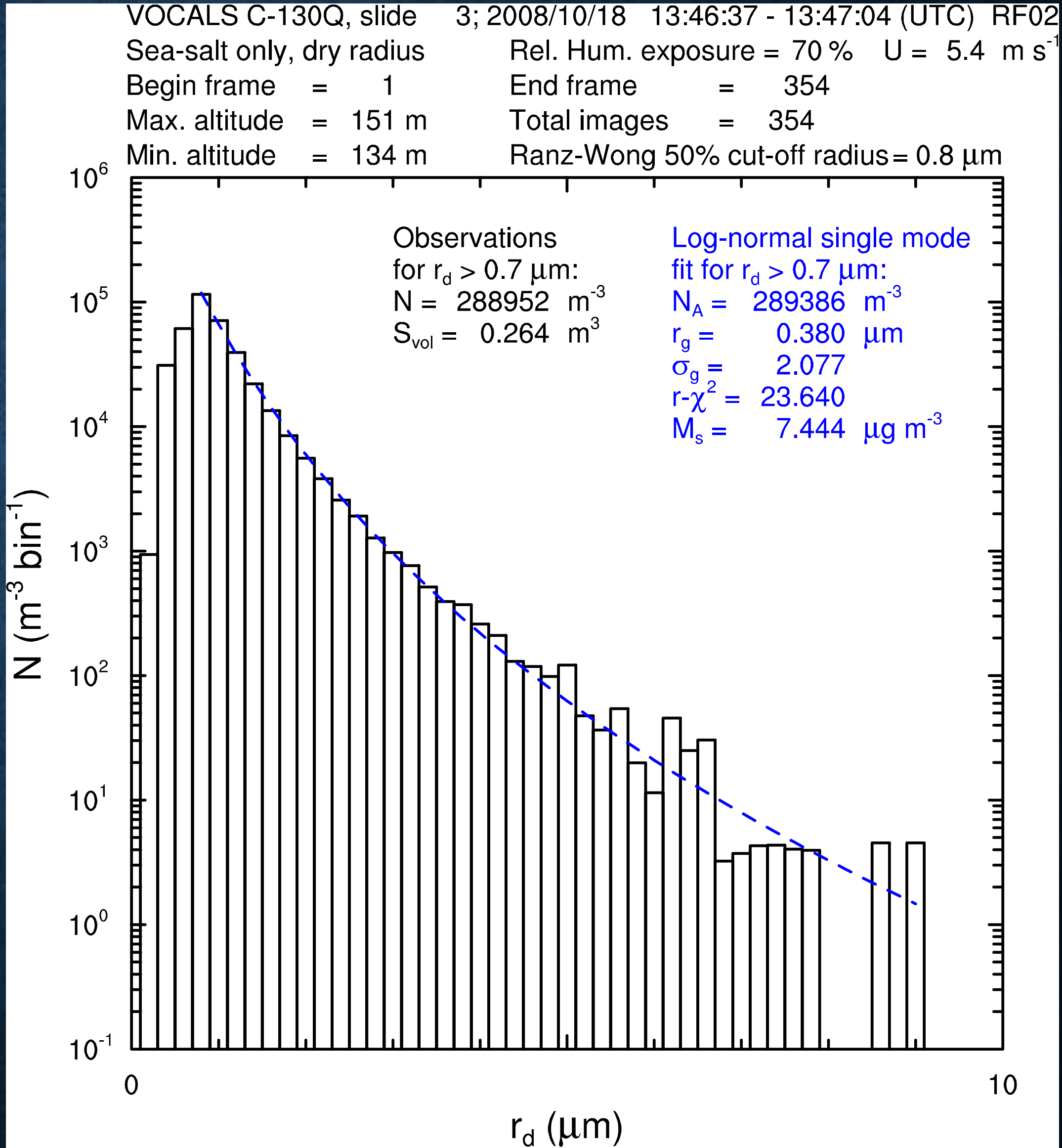






Sea-Salt Aerosol Size Distribution

Example size distribution from 1 of 238 slides from the VOCALS field campaign



Current sampling techniques require aircraft, are limited in space and time, and are $$$

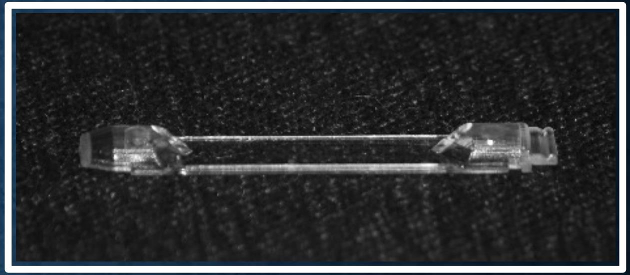
How can we observe changes in GCCN size distribution with altitude, wind speed, seasons, sea-state, temperature etc?

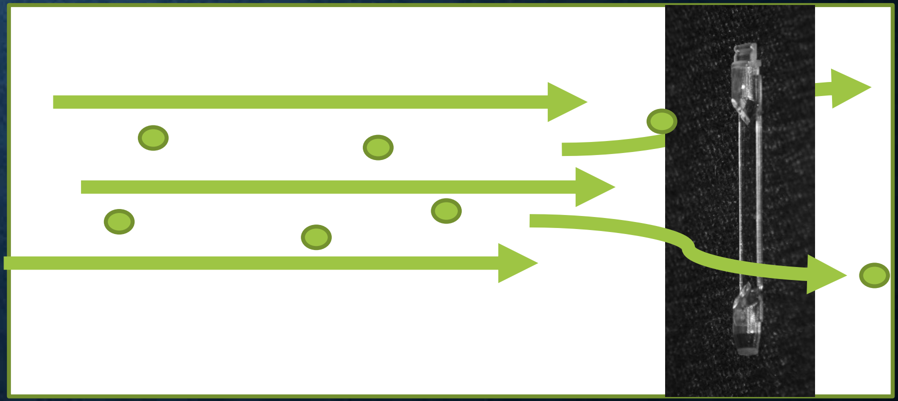
With a ground-based kite platform!

OBSERVING NEEDS

The polycarbonate slide should:

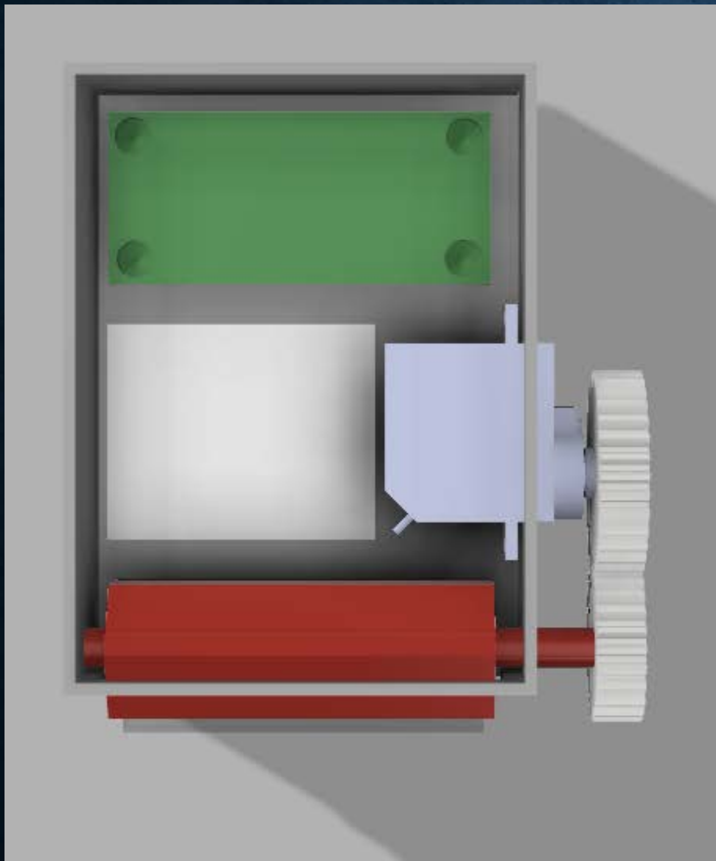
- Be exposed, <u>only</u> when sampling
- Steadily face perpendicular to the wind
- Not be on anything wider than the slide itself

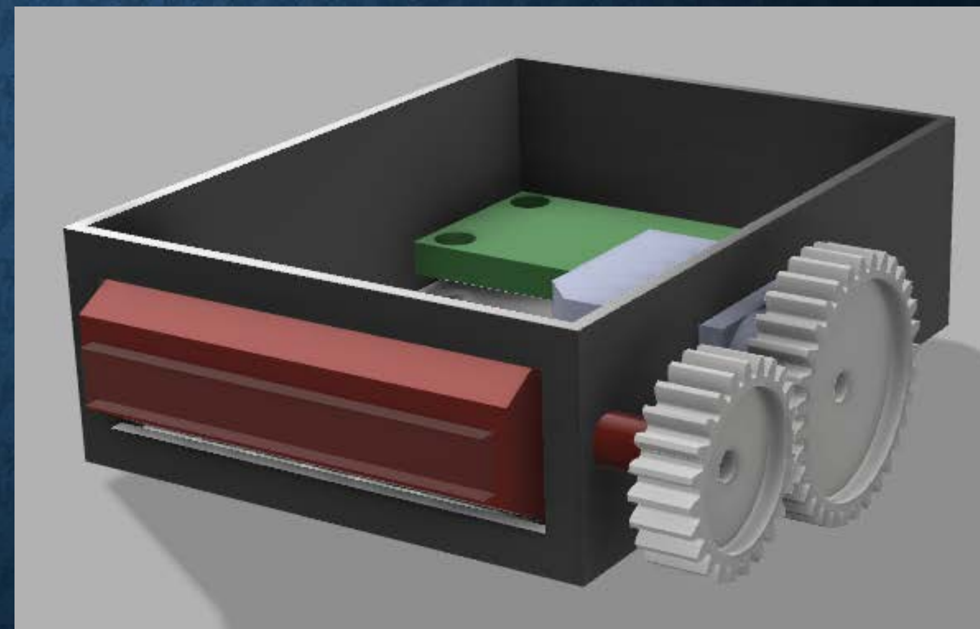




Other Needs: lightweight, flyable by kite, self orienting and 2-way communication

POTENTIAL PROTOTYPE



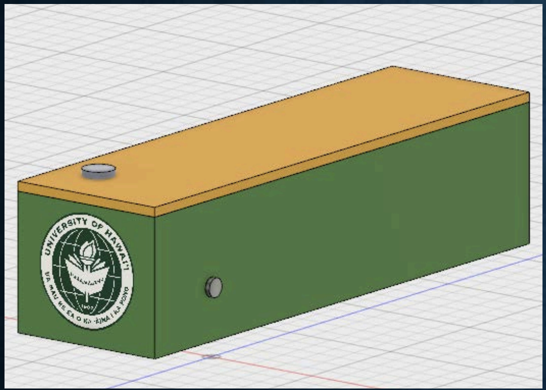


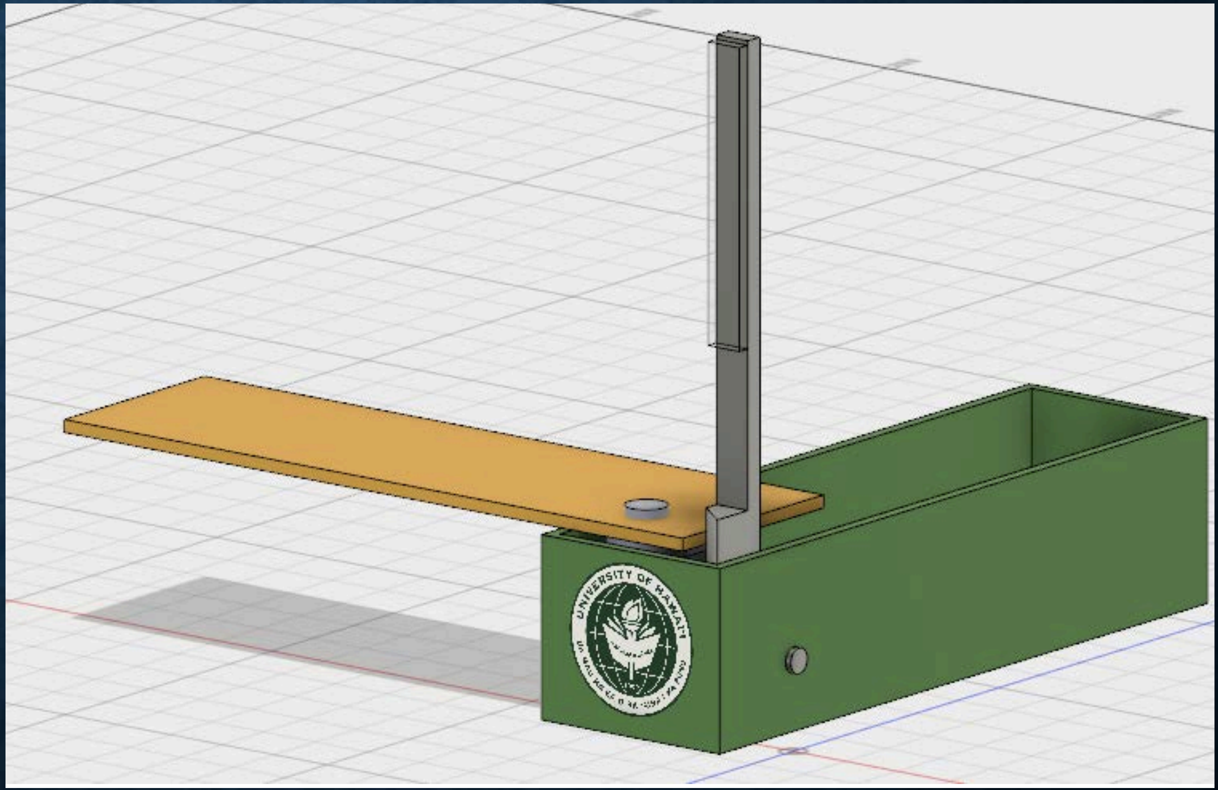
What's wrong with this design?

POTENTIAL PROTOTYPE

Different design, same issue…

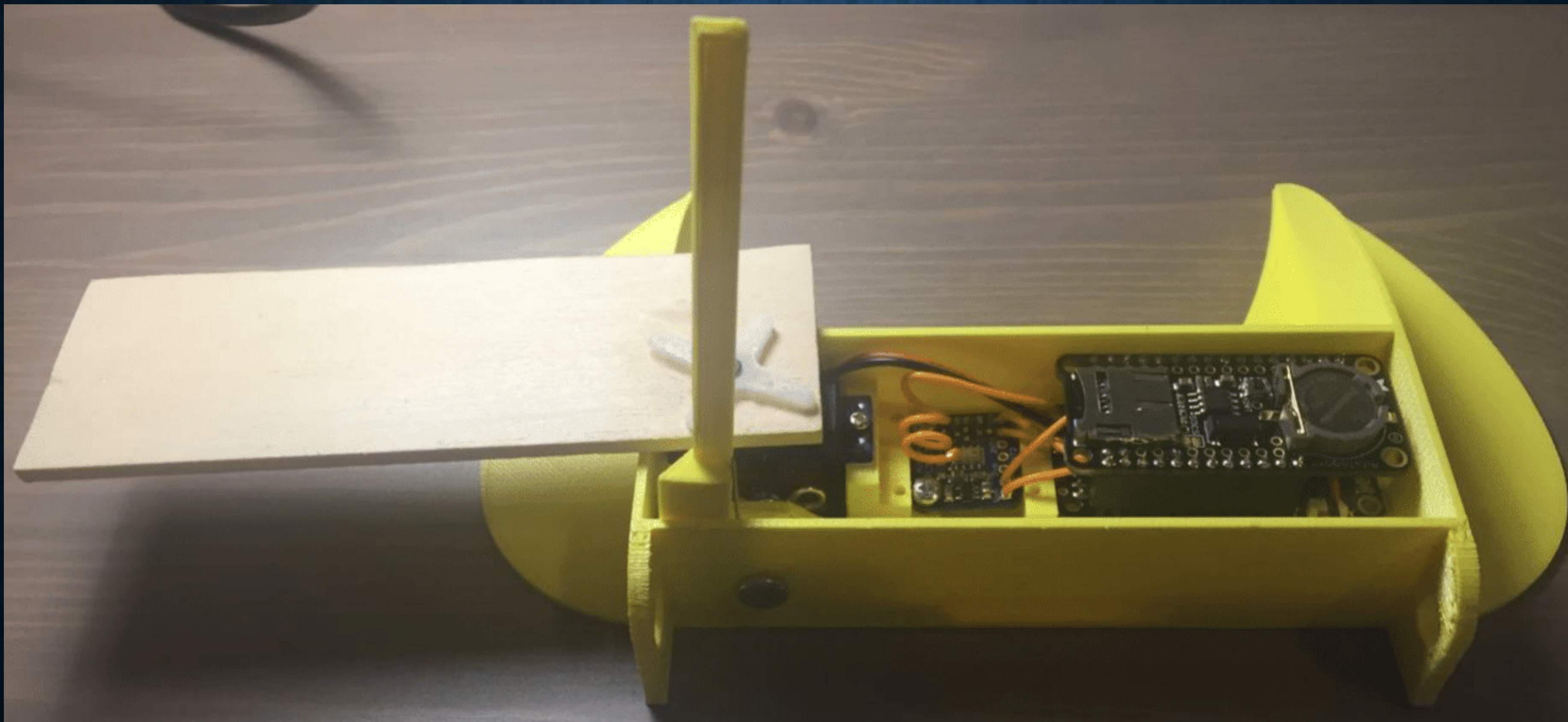
POTENTIAL PROTOTYPE





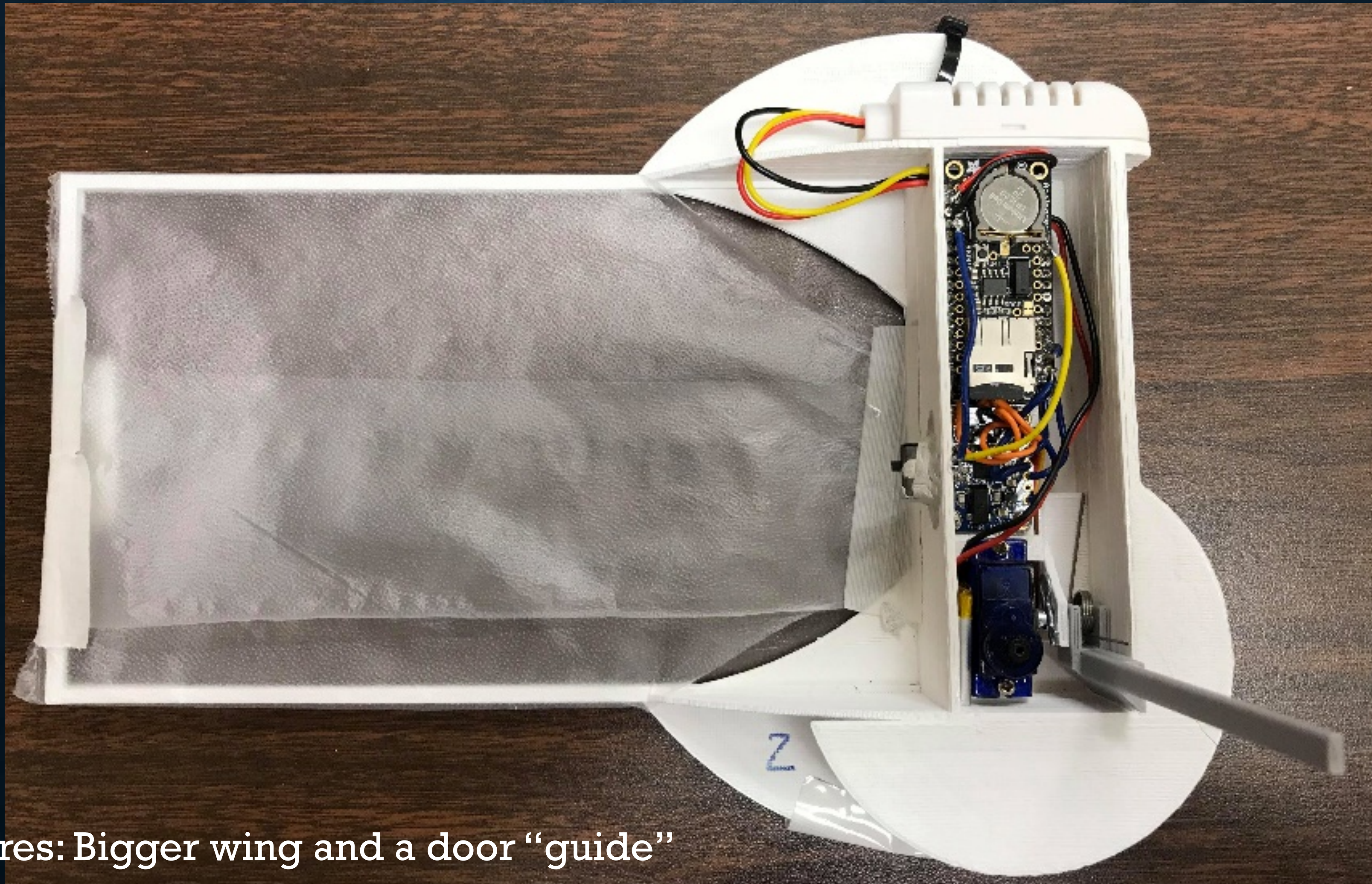
What are the issues with this design?

GETTING CLOSER….



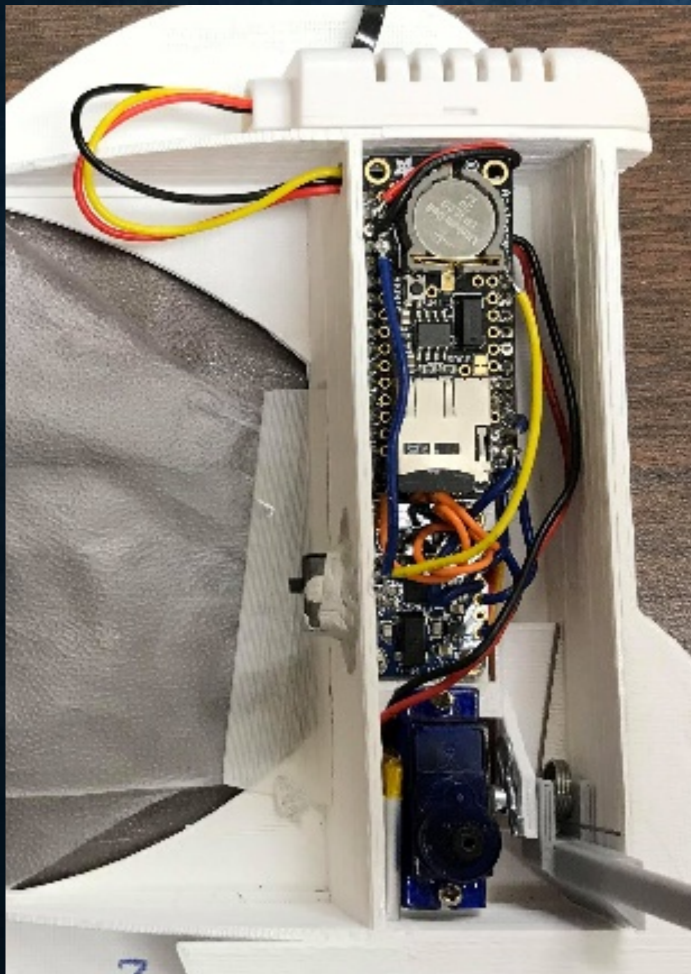
Added a "wing", slide oriented correctly, but still a few problems.

THE FINAL DESIGN



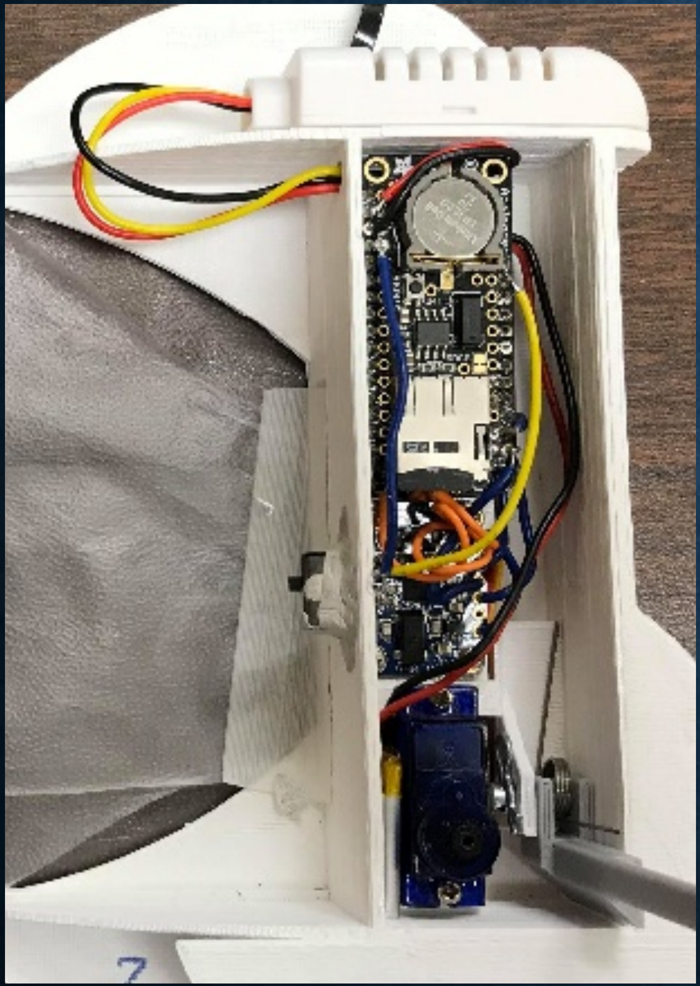
Features: Bigger wing and a door "guide"

ELECTRONICS NEEDS



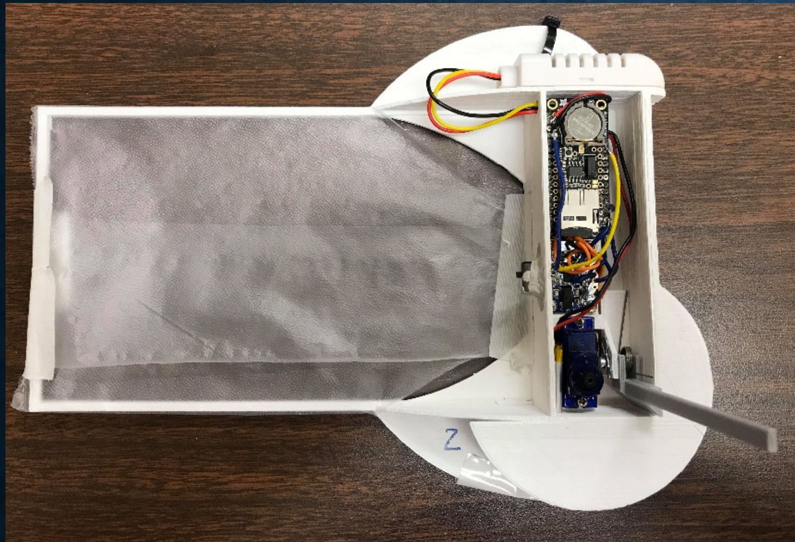
- Pressure, temperature, and humidity measured in-situ when sampling sea-salt
    - High frequency data, but data also transmitted
- Ability to open and close the door remotely
- Ability to know if the door is open or closed, and for how long, to calculate sample volume
- Orientation to be sure the slide is perpendicular to the wind
- 2-way communication to a ground station

ELECTRONICS



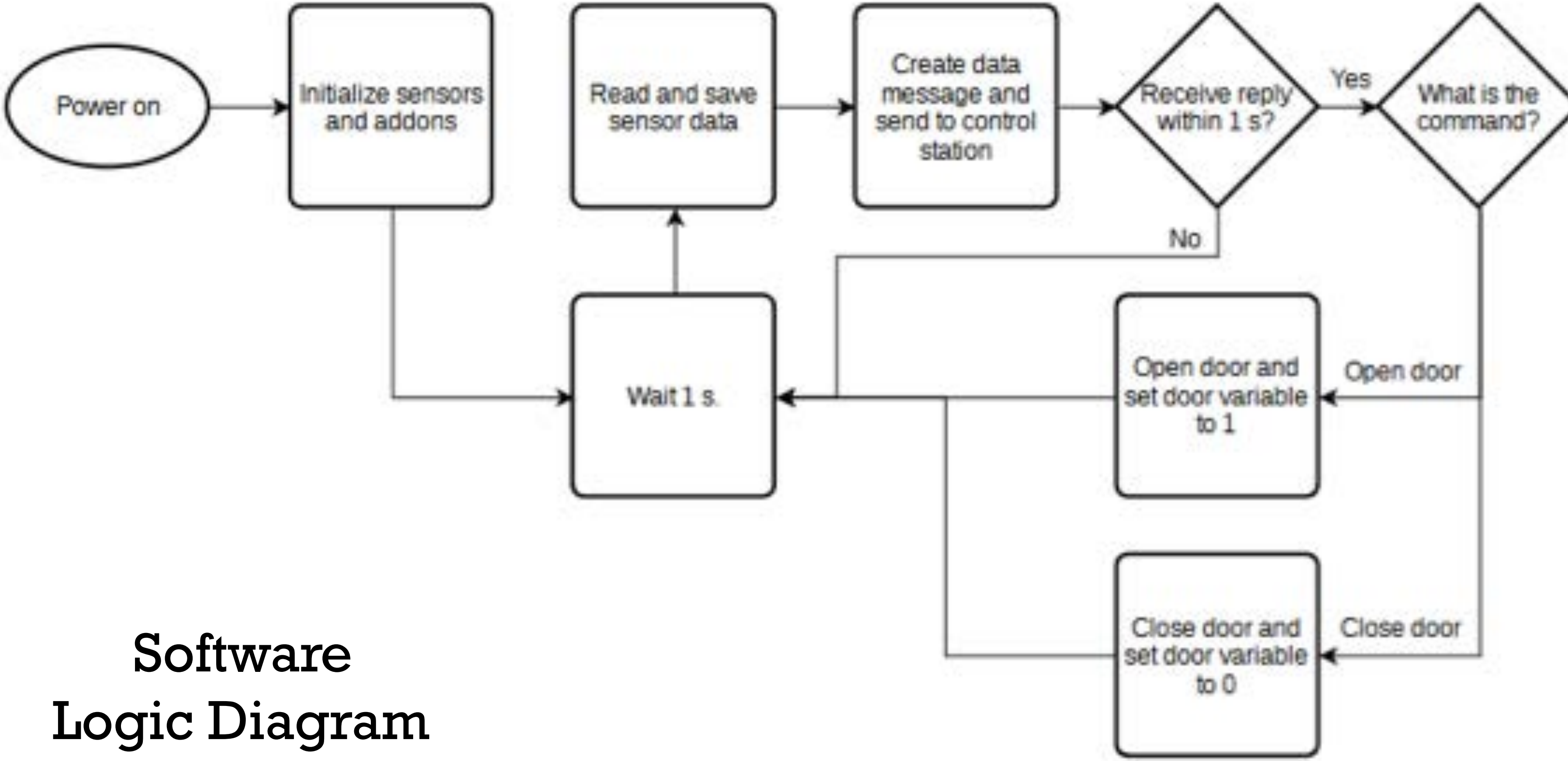
- Arduino (Feather M0) + datalogger
  - Datalogger holds SIM card
  - Antenna wire soldered to Arduino
- MPL3115A2 – I2C Barometric Pressure Altitude Temperature Sensor
- Servomotor that can open and close door
- 9-DOF Absolute Orientation IMU Fusion Breakout BNO055
- AM2302 (wired DHT22) temperature humidity sensor

THE MINI-GNI INSTRUMENT



- Adalogger saves sensor data to micro SD card
- Micro servo motor rotates door exposing arm where slide is attached

- Commanded using LoRa from touchscreen on the ground
- Altitude, temperature, relative humidity, and whether the door is open or shut is transmitted to and displayed on the ground station



Software Logic Diagram

OTHER MATERIALS

- Electric Fishing Reel
- Deep Cycle Battery
- Tripod
- Delta Conyne Kite
- Braided Fishing Line, 80 lb test

ATTACHMENT

- Taut kite string wrapped around carabiner
- Mini-GNI is attached to kite with a carabiner and a zip tie
- Wings orient it to the wind

EXPOSURE STEPS

1. Launch kite and attach mini-GNI
2. Extend kite to desired altitude
3. Expose slide at altitude via remote control
4. Sea-salt aerosols impact onto slide exposed to the free airstream
5. Cover slide at altitude
6. Reel in kite
7. Recover slide
8. Analyze slide in a lab

SLIDE EXPOSURE

- The slide extends perpendicular to the wind direction
- Slides are exposed for

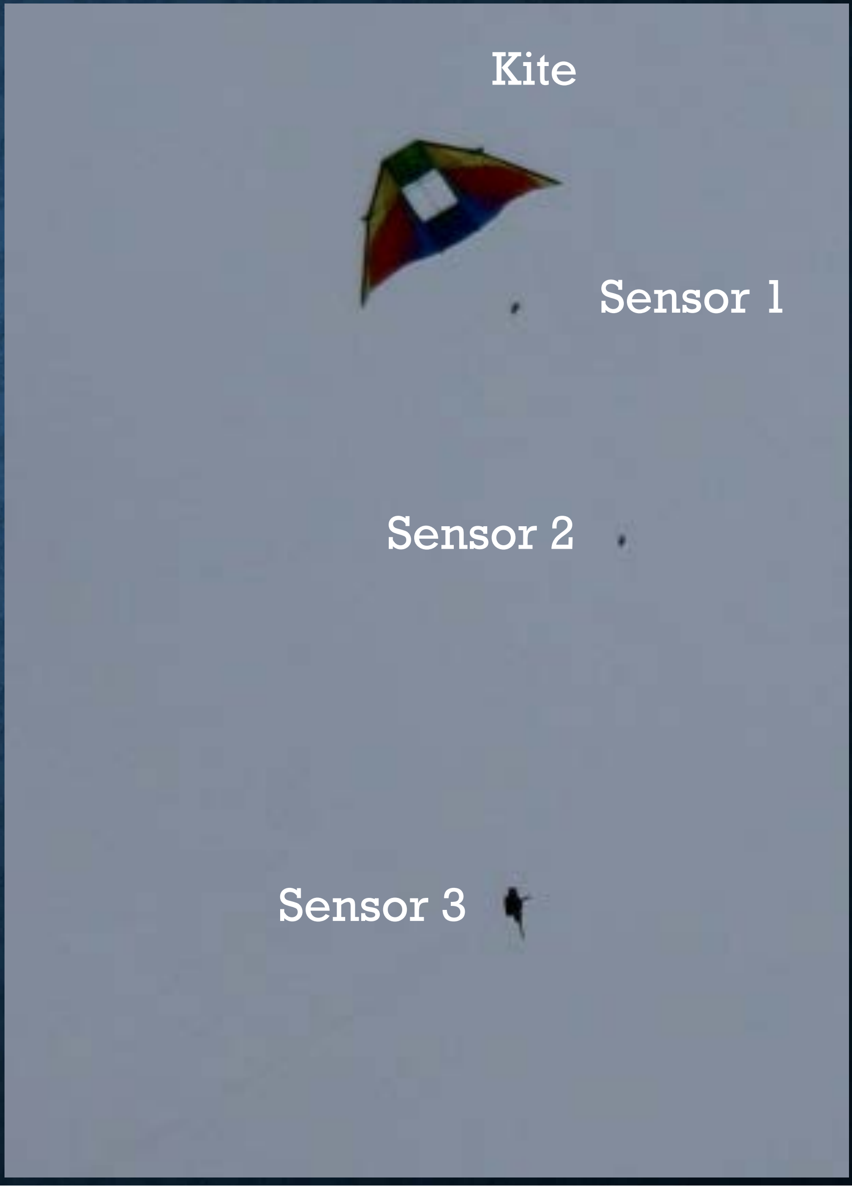
~10 min

- Salt impacts onto the slide

- Apparent wind speed is the largest difference between sampling by aircraft and on a stationary kite platform

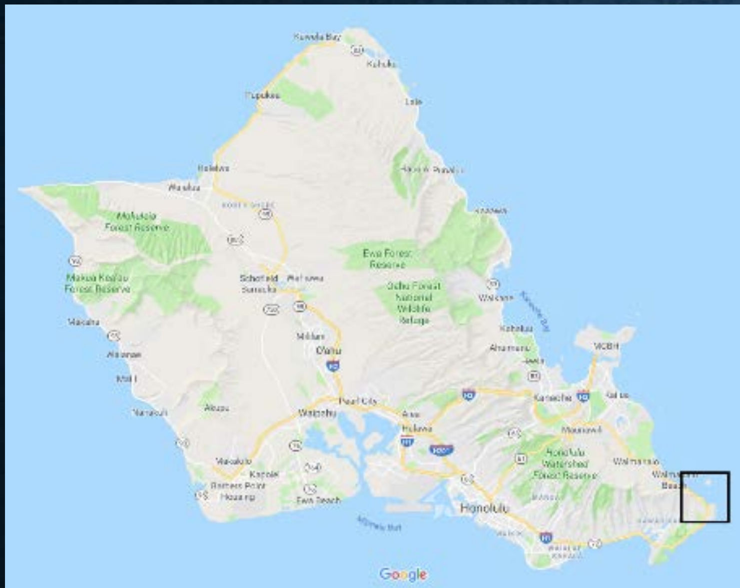
KITE PLATFORM

- Multiple mini-GNIs attached to the same kite string allow simultaneous sampling at multiple altitudes




VIEW OFFSHORE

SAMPLING SETUP



At the ground, the electric fishing reel holds the kite string, and the battery anchors the kite to the ground

Setup is on the windward side of Oahu Island

Setup is ~25 m away from the shoreline, and ~5 m above sea level

WIND MEASUREMENTS

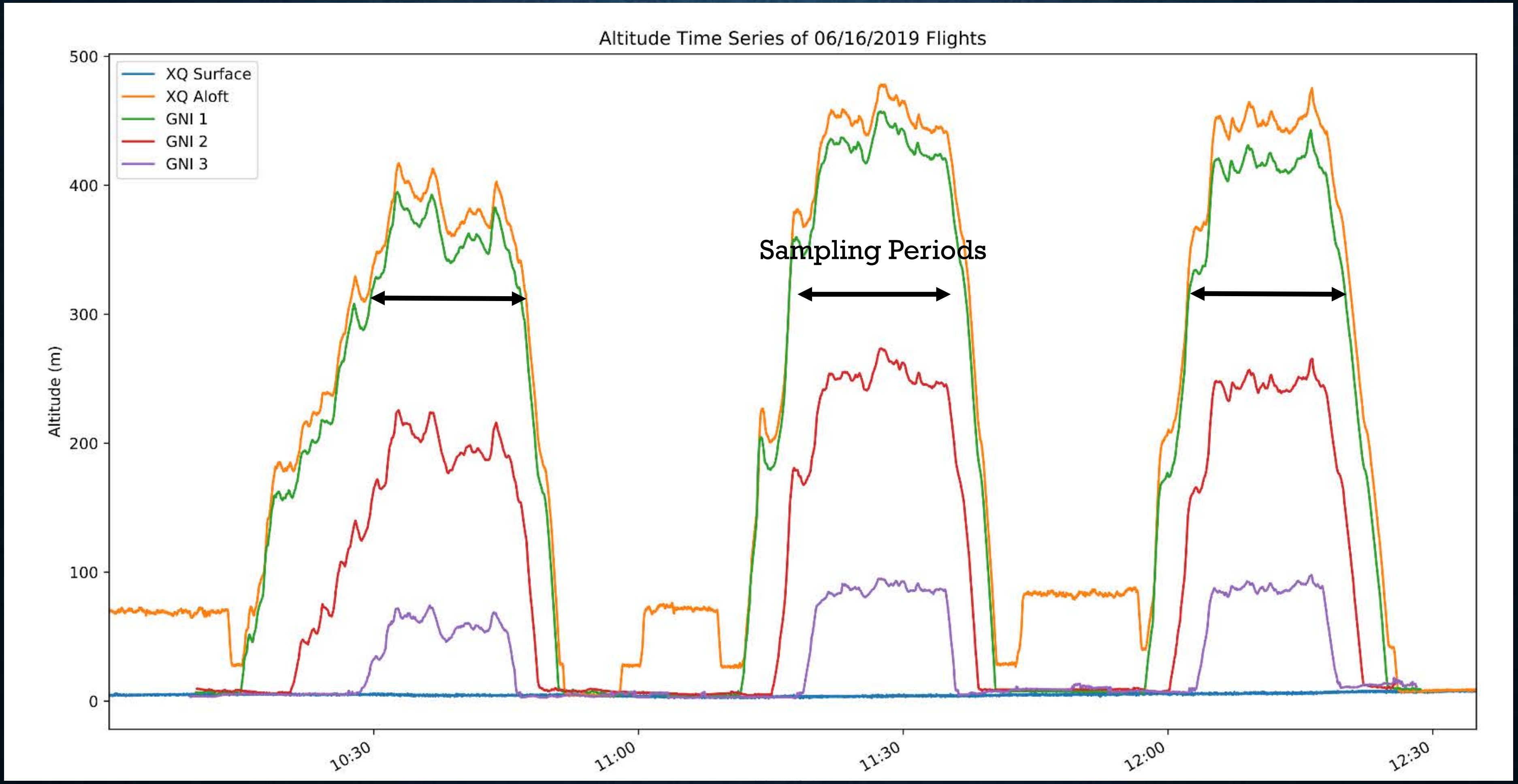
- Kestrel set up to measure wind at the ground surface
- Wind comes from offshore
- Wind speed aloft is calculated using the power law

$$u = u_s \left(\frac{z}{z_s}\right)^{\alpha}$$

u=wind
z=height
s=surface

$\alpha = \frac{1}{7}$ (applicable over open land under neutral stability)

EXAMPLE PLOT FROM SAMPLING DAY 6/16/19



OTHER SAMPLING

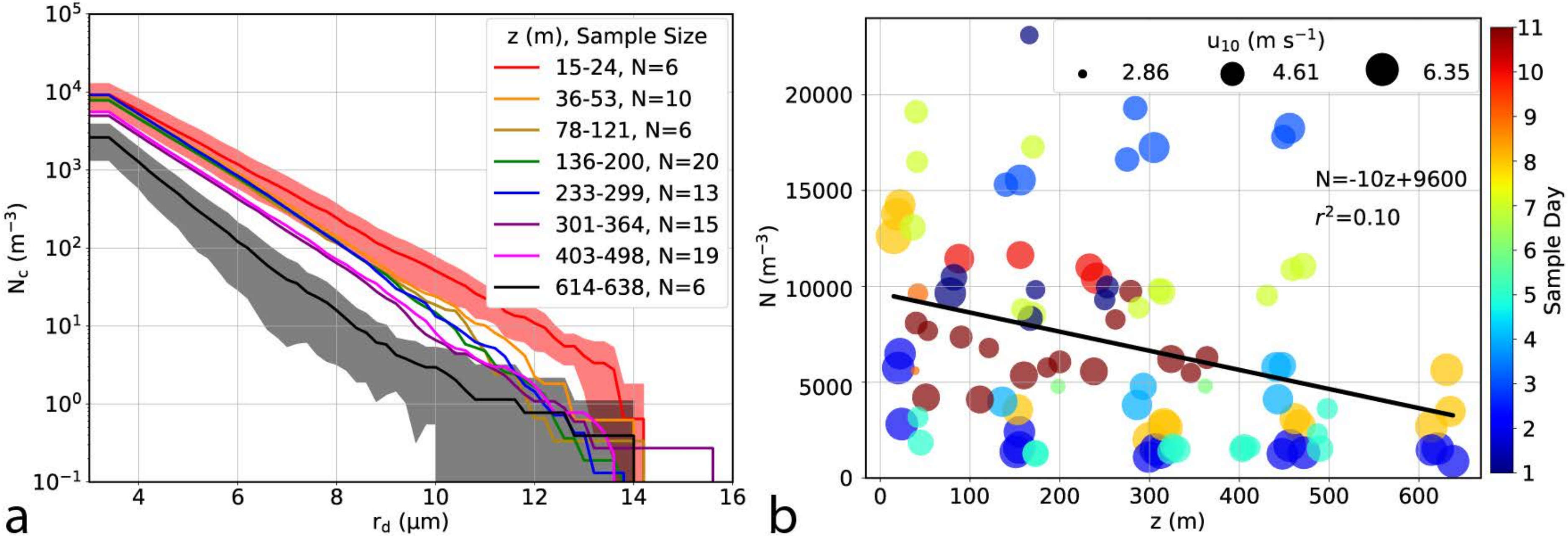
- By Drone

Sampling offshore by drone helps to determine how wave breaking on the reef crest affects the size distribution


DRONE FOOTAGE

DRONE FOOTAGE

EXAMPLE RESULTS



Sea-salt aerosol decreases in size and number with altitude

CONCLUSIONS

We’ve developed a simple and economical way to observe the sea salt aerosol size distribution

- 3D print design & wiring diagram are publically available on a shared github page: https://github.com/nugentlab/miniGNI
- All Arduino parts are purchased from Adafruit
- Total cost is <$150 per mini-GNI

nugentlab / miniGNI

Notifications

<> Code | Issues | Pull requests | Actions | Projects | Wiki | Se

master ▾ | Go to file | Code ▾

nugentlab Update README.md ... on Oct 5, 2020 52

	SSA_Analysis	Rename ssa_reader_functions.py to
	SSA_Plot_Codes	Rename SSA_Plot_Codes/ssa_buoy_
	miniGNI_Analysis_Code	Rename miniGNI_plotter.py to miniG
	miniGNI_Assembly	Add files via upload
	pics	Add files via upload
	ranzwong_code_refere...	updataes
	README.md	Update README.md

1. Construct your own Mini-GNI

This directory provides the information necessary to create your own mini-GNI. It's contents are filled with all of the STL files necessary for 3-D printing, in addition to the coding for the arduino microcontroller within the mini-GNI and the arduino within the base controller (the controller used to connect with the mini-GNI while it is aloft). An assembly diagram is provided as well.

To download this directory from GitHub, run:

```
git clone https://github.com/nugentlab/miniGNI/miniGNI_Assembly
```

Questions?

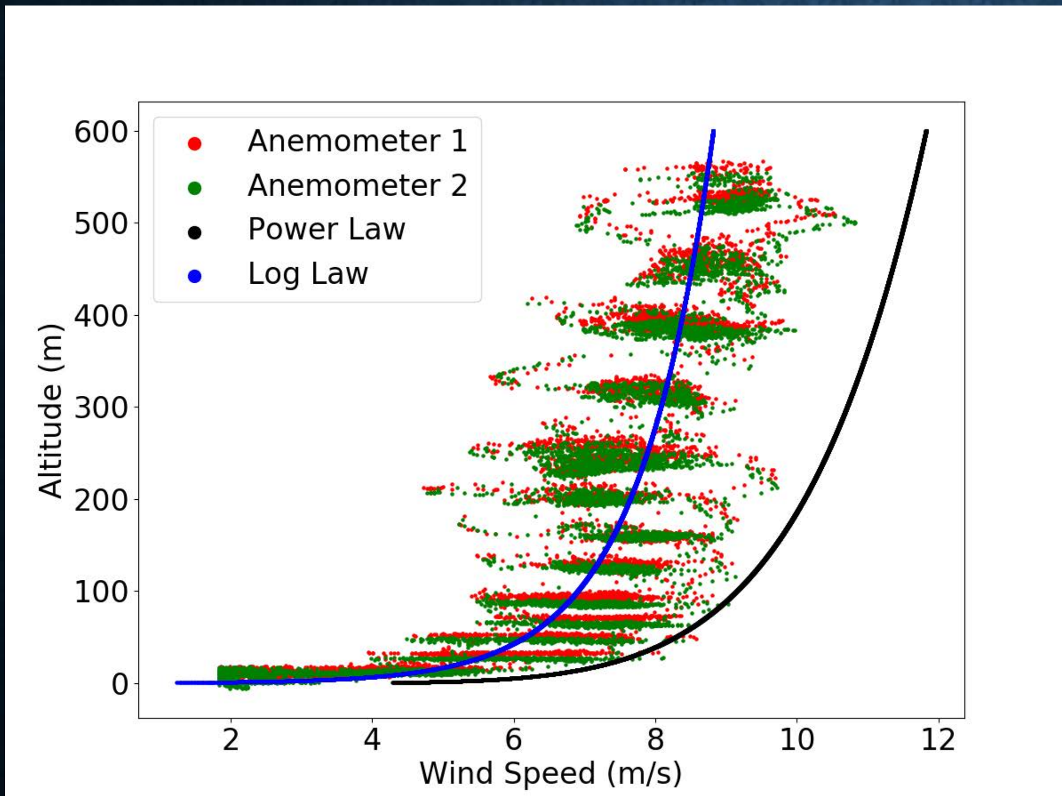
Funded by:
NSF EAGER Grant 1762166: A new method for sampling sea-salt aerosols

Emails: anugent@hawaii.edu, klackerm@hawaii.edu

WIND PROFILE TEST

- Custom anemometers built to test wind profile law
- Similar to mini-GNI, built with 3D printing and Arduino technology and can be attached to kite string
- Has modified computer fan to measure wind speed
- Fans without 3D casing were calibrated in wind tunnel

WIND PROFILE TEST



- 3 October 2019, attached two anemometers to kite string and left them at various altitudes for about 10 minutes each while Kestrels measured surface wind.
- Result fits log law:
- $u = 1.062 * \ln(z) + 2.028$
- According to these results, we are overestimating wind.
- Is this observation representative of typical sampling day?

IMPLICATION OF WIND SAMPLING

- If our 10/3 wind profile can be considered representative of a typical sampling day, then the wind speeds we estimated for each sample should be decreased by 35%!
- What are the effects of changing wind speed by 35%?
- $Number\ Concentration = \frac{1}{Collision\ Efficiency} * \frac{Raw\ Count}{Slide\ Area*Wind\ Speed*Sample\ Time}$
- Recall that wind speed affects both sample volume and collision efficiency.