DEVELOPING AN ARDUINO PACKAGE TO PROBE ACTIVE DUST DEVILS WITH A DRONE. Justin Crevier[1] (justincrevier@u.boisestate.edu), Chelle Szurgot[1], Brian Jackson[1], and Ralph Lorenz[2] [1]Department of Physics, Boise State University, 1910 University Drive, Boise ID 83725-1570 USA; [2]Applied Physics Laboratory, Johns Hopkins University, Laurel MD 20723-6099 USA(Ralph.Lorenz@jhuapl.edu).

Introduction: Dust devils are dry, low-pressure vortices that lift dust and have diameters of a few to several hundred meters. They occur wherever atmospheric conditions can support convection, and the surface-atmosphere interaction allows aeolian transport of dust grains. On Earth environments, dust devils may contribute 30+% to the global dust budget [1], and on Mars they may also contribute a significant percentage of the planetary dust budget [2]. However, the physical relationships between a dust devil's internal structure (pressures, wind field, etc.) and its dust-lifting capacity are unclear. To probe these relationships in active dust devils, we are developing an instrument package small enough that it could safely fly on a commercially-available drone, the DJI Mavic 2.

We are currently upgrading our drone's onboard sensor package to collect data on dust particle number density and size, using off-the-shelf commercial sensors, and are refining our sensor package to improve our temperature collection. Our initial data collection runs on dust devils at a field site in rural Oregon (The Alvord Desert) and a field site just outside of Las Vegas (El Dorado Playa, Figure 1) have shown modest success, and we are able to recover reasonable dust densities and pressure/temperature structures within dust devils.

Challenges: Our Mavic Pro 2 drone is built around a high-quality gimbaled camera. The drone weighs 905 grams, and has a rated maximum takeoff weight of 1100 grams [3] - which leaves very little carrying weight available for sensors and accessories. FAA regulation of drones additionally requires that any payload does not adversely affect the pilot's ability to control the aircraft.

To pursue a dust devil in the field, we must first spot a dust devil near enough (within 500 meters) that we can safely approach and encounter. The drone's top speed is about 20 m/s (40 mph), and it can safely navigate winds of about 11 m/s (22 mph), allowing us to safely encounter typical dust devils. Drone launch and lift characteristics play critically important roles in this process (Figure 2).

Balancing Sensor Mass, Capability, and Performance: Our sensor payload is based on two primary components, which we can program and control through an onboard computer using the C programming language via the Arduino IDE (Integrated Development Environment). These primary components include an Adafruit Data Logging shield mounted on an Arduino Uno R3 microcontroller board (Figure 3). The Adafruit Data Logging System holds an SD card and can simultaneously log from a set of lightweight, modular pressure, temperature, and dust sensors for drone flights. We are using the GY-68 BMP180 sensor module series to measure temperature and pressure--with a mass of only 5 grams, this sensor can record pressure ranges of 300 ~ 1100hPa (+/- 0.06 hPa) and temperatures to within a 0.1 degree C range, with a manufacturer's listed reaction time of 7.5 ms. The R3, Adafruit, SD card, and BMP180 sensors have a combined mass of 157 grams, which gives us leeway to experiment with several different sensor combinations.

"Off-the-Shelf" Dust Sensors Limitations and Selection: Given our increased focus on dust-particle grain size, we have reviewed and tested several dust sensors that are compatible with the Arduino IDE and operating system. Although there is a broad range of lightweight commercial dust sensors available, most of these are optimized for industrial uses; either their particle size detection range or their response time (or both) fall outside of our operating parameters.

Response time is particularly important to us, given the drone's very short direct exposure time to a dust devil – this can be as little as 5-10 seconds in a typical intercept flight. We are currently working with the Waveshare GP2Y1010AU0F, which has displayed consistently rapid response times and baseline returns; detects dust particles at sizes of 1 micrometer level and greater; and adds 41 grams to overall payload weight.

References

[1] M. Klose and Y. Shao. A numerical study on dust devils with implications to global dust budget estimates. *Aeolian Research*, 22:47–58, 2016. doi:10.1016/j.aeolia.2016.05. 003. [2] L. Fenton, et al. Orbital Observations of Dust Lofted by Daytime Convective Turbulence. *Space Science Reviews*, 203:89–142, 2016. doi:10.1007/s11214-016-0243-6. [3] SZ DJI Technology Ltd. (2019). Mavic 2 Enterprise Series: User Manual. Los Angeles, California: Author.

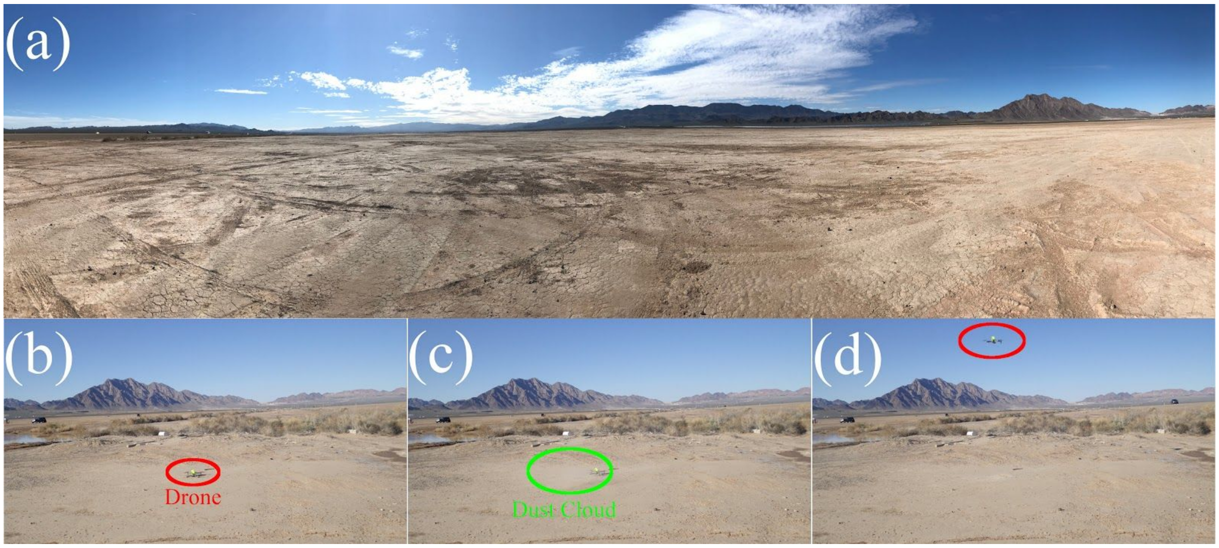

Figure 1: (a) El Dorado Playa. (b)-(d) Five-second launch sequence, generating dust cloud.

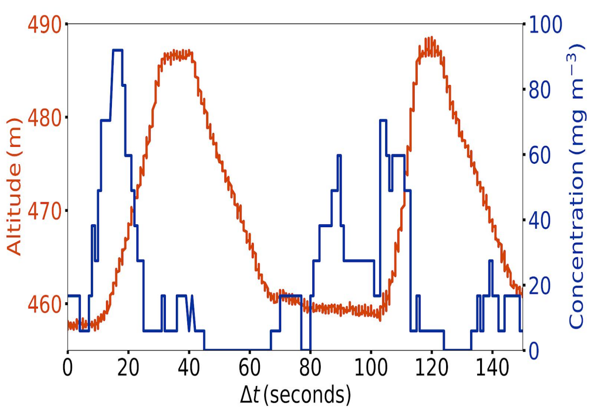

Figure 2: Drone altitude (orange) and dust concentration (blue). The drone's propellers begin spinning up just before launch (when the altitude increases), generating a cloud of dust that registers in the dust sensor. Upon landing, another cloud is generated, too.

Figure 3: The Mavic 2 drone with the sensor package attached.