USING AN INSTRUMENTED DRONE TO PROBE DUST DEVILS. B. Jackson[1] (bjackson@boisestate.edu), R. D. Lorenz[2], K. D. Davis[1], and B. Lipple[3]. [1]Dept. of Physics, Boise State University, [2]Johns Hopkins University Applied Physics Laboratory, [3]Empire Unmanned.

Introduction: Dust devils are low-pressure, small (many to tens of meters) convective vortices powered by surface heating and rendered visible by lofted dust. Dust devils occur ubiquitously on Mars, where they significantly contribute to the supply of atmospheric dust, and since dust contributes significantly to Mars' atmospheric heat budget, dust devils probably play an important role in its climate. The dust-lifting capacity of a devil likely depends sensitively on its structure, particularly the wind and pressure profiles, but the exact dependencies are poorly constrained. Thus, the exact contribution to Mars' atmosphere remains unresolved. Analog studies of terrestrial devils have provided some insights into dust devil dynamics and properties but have been limited to near-surface (few meters) or relatively high altitude (hundreds of meters) sampling. Automated aerial vehicles or drones, combined with miniature, digital instrumentation, promise a novel and uniquely powerful platform from which to sample dust devils at a wide variety of altitudes. In this contribution, we will describe a pilot study using an instrumented quadcopter on a field site in southeastern Oregon, which (to our knowledge) has not previously been surveyed for dust devils. We will present preliminary results from the encounters, including stereo image analysis and encounter footage and pressure profiles collected onboard the drone during flight. Most importantly, our study shows a quadcopter can successfully navigate an active dust devil.

Field Setup: For our pilot study, we visited the Alvord Desert (Figure 1), a roughly 7 x 12 km dry lake bed in southeastern Oregon. As a local catchment for infrequent rain and snowmelt, the Alvord playa is layered with brightly colored, fine silt, ideally suited for visualizing active convective cells and producing dust devils. Indeed, reports from the owners of the Alvord Desert Hot Springs, located adjacent to the playa, suggested frequent dust devil activity which we confirmed via a short time-lapse survey.

For our drone survey, we visited Alvord on 2017 July 20 and 21. After an initial unsuccessful attempt to actively pursue dust devils from our vehicle on July 20, we established a fixed launch site on the playa's western margin from which we launched the instrumented drone and videoed the dust devil encounters on July 21.

We used simple point-and-click cameras, Ricoh WG-5 GPS, which have a pixel resolution of 1920 x 1080 and field of view of 71.5° x 40.2°. A pair of cameras was mounted on a standard monopod with a stereoscopic mount bracket, giving a separation between the camera apertures of 0.18 m. With an angular resolution of 0.1°, this setup allowed us to estimate stereo-parallaxes to a distance of about 80 m.

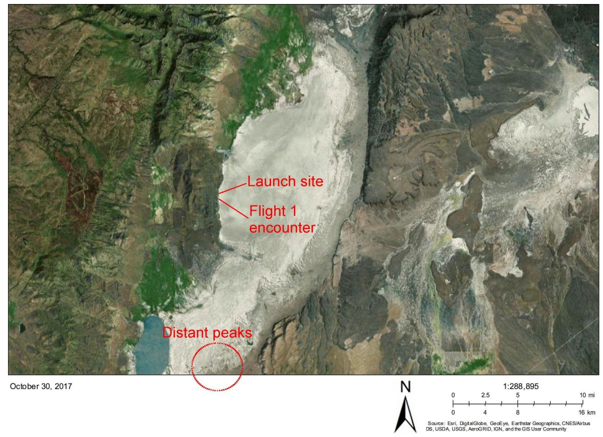

Figure 1: Landsat image of Alvord Desert, courtesy of NASA Goddard Space Flight Center and the U.S. Geological Survey. The figure shows the approximate launch site, adjacent to the playa access road, and the location of the Flight 1 dust devil encounter. The distant peaks against which we estimated parallax are also shown.

To map dust devil pressure profiles from onboard the drone, we used a commercially available pressure logger, the B1100-1 by Gulf Coast Data Concepts, used in previous dust devil studies [1]. We collected pressure time-series at 2 Hz, and turbulent pressure excursions during flight resulted in an effective measurement uncertainty of about 0.3 hPa.

We also used a 3DR Solo drone, a 1.5 kg quadcopter spanning about 46 cm diagonally from propeller to propeller and standing about 25 cm off the ground. The Solo has a payload capacity of 500 g and is capable of flying in winds of about 11 m/s (25 miles-per-hour), less than is typical for many dust devils. The drone beamed its GPS location and altitude back to a hand-held controller at 5 Hz and carried a gyro-stabilized GoPro 3 Silver camera, a live feed of which was also transmitted back to the controller. We mounted the pressure logger on the bottom of the drone and collected continuous pressure time-series before, during, and after flight through active devils.

Figure 2: Still from the video collected during Flight 1. The drone (top left) appears in frame and heads toward the dust devil (middle), approximately 3 seconds after launch.

Results: Figure 2 shows a still from one of the stereo-videos collected during Flight 1. To conduct our stereo analysis, we used the distant peaks (17 km away) as an anchor point and in each frame (1 per second) measured the pixel offset from the rightmost peak to the dust devil, converting it to an angle. With this angle measured in the left (α_L) and right (α_R) camera images, we estimated the distance to the dust devil, 80 m, consistent with the drone's flight time. We also estimated the dust devil's diameter, 1.8 m.

During flight, we collected pressure and altitude time-series onboard the drone, as shown in Figure 3. The pressure signal is dominated by the hydrostatic drop/increase as the drone ascends/descends, potentially masking the small, negative excursions due to dust devil encounters. Therefore, we subtracted a linear regression to the pressure vs. altitude data (plot not shown), leaving the residual pressure signal in Figure 4. Although the drone's rotors produce a ground effect spike in the pressure, we see no other evidence for significant distortion by the aircraft.

To the residuals in Figure 4, we fit Lorentz models to estimate the dust devil's pressure profile [2]. In Figure 4, the red model attempts to incorporate turbulent excursions other than the dust devil itself. Folding in the known drone velocity at the time of encounter, we estimated a diameter for the devil from the pressure signal analysis consistent with that from the stereo analysis.

Conclusions: During our field survey, we achieved four successful dust devil encounters without any difficulty passing through the devils. Future surveys will include additional instrumentation to more accurately probe devil structures, including direct measurements of the dust densities similar to [3]. We also plan to apply an analysis technique [4] to reconstruct devil dust column abundances from the imagery data. The work described in this abstract is published in [5].

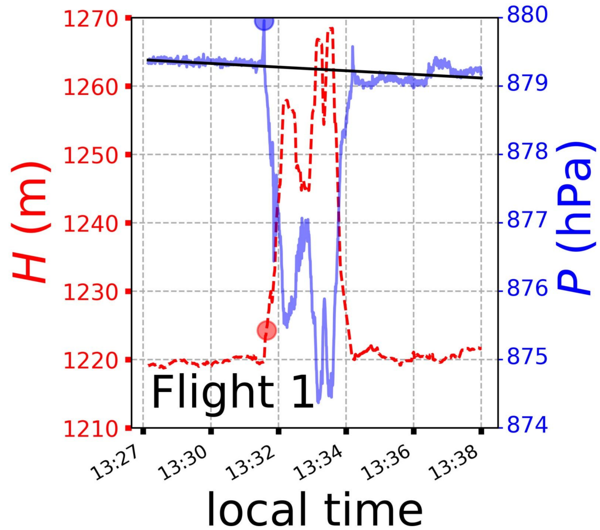

Figure 3: Altitude H in meters (red, dashed line) and pressure P in hPa (blue, solid line) vs. local time during Flight 1.

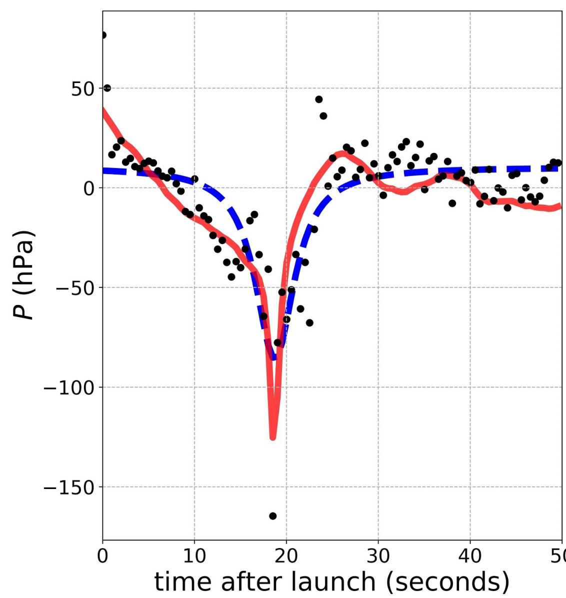

Figure 4: Pressure signal from Figure 3 after removing hydrostatic trend. The solid, red line shows a model fit incorporating additional turbulence, while the dashed, blue line does not.

References: [1] Lorenz, R.D. (2012) *Geosci. Inst. Methods and Data Sys. Disc.,* 2, 477–505. [2] Jackson, B. & Lorenz, R. (2015) *JGR: Planets,* 120, 401. [3] Raack, J. et al. (2017) *Astrobio*. [4] Greeley, R. et al. (2006) *JGR*, 111, E12. [5] Jackson, B. et al. (2018) *Remote Sensing*, 10, 65.

Additional Information: YouTube videos of several of our dust devil encounters are available at www.astrojack.com/research.