FAU Harbor Branch SLP-Funded Research Project
Sponsor: Harbor Branch Oceanographic Institute Foundation

Annual Report

1. Project Title: CLOUD- Comprehensive Landscape Observation via Unmanned Drone

2. Specialty License Plate (SOS,AQUA, PWD, PFW): SOS

3. Personnel involved in the Project in FY2016:
   PI: Joshua Voss
   Student: Michael Studivan (G),
   Collaborators: Jeff Beal (FWC), SFWMD, Martin County

4. Performance Period: Jan 1, 2015 through Oct 31, 2015

5. Accomplishments/deliverables:

(*Accomplishments/deliverables toward project goals and objectives (e.g., manuscripts, presentations, completion of experiments, graduate students, leveraging SLP for external funds*).

In late fall 2014 and spring 2015 we developed our imaging capabilities using a DJI Phantom Vision 2+ unmanned aerial vehicle. However it was not until June 2015 when we purchased a new DJI Inspire quadcopter system and ramped up Project CLOUD in earnest. Through a combination of flights on the Harbor Branch Campus and at research sites, we tested and developed a series of protocols and recommendations for using UAVs to conduct scientific research. These results are summarized in the "Project CLOUD: best operational practices for UAVs" draft document attached at the end of this report. We completed aerial surveys in 5 discrete habitat types: salt marsh, oyster reefs, dragline ditch restoration sites, estuary/inlets, and coral reefs. In addition we completed a video survey of the entire HBOI campus.

We also successfully completed 6 outreach videos (1 more than originally anticipated) utilizing video footage from the DJI Inspire. Of these 5 have been posted on YouTube and distributed through social media, ultimately generating more than 8000 online views and attention in local media. The last is under review by the HBOI Communications Team.

Outputs:
Videos
"Harbor Branch-FAU & Project Baseline Oculina Cruise 2015"
Length 5:22 https://youtu.be/Buw58l9xxgs

“FGBNMS ROV Cruise 2014 & 2015”
Length 6:46 https://youtu.be/2nC9VPGiI-s

“Black & Blue: Estuarine Discharge on St. Lucie Reef”
Length 5:29 https://youtu.be/PynakC9ipkk

“Taking Science to the Sky: Quadcopter Restoration and Photomerging”
Length 5:42 https://youtu.be/CUcW2Yru4HQ

“Freshwater discharges impact the Indian River Lagoon and St. Lucie Inlet Preserve State Park”
Length 2:36 https://youtu.be/1FgBon2CAwM

“FAU Harbor Branch Aerial Tour”
Length 5:23
Submitted to HBOI Communications team

Voss JD, Studivan MS. 2016. Project CLOUD: best operational practices for UAVs. Draft document for use by other HBOI faculty involved in UAV operations.

Treadway T. 2016. Black water plume from St. Lucie River threatens offshore coral reefs. TCPalm newspapers coverage including lead cover story in Stuart News based on interview with Voss. Feb 17, 2016. http://www.tcpalm.com/news/indian-river-lagoon/health/black-water-plume-from-st-lucie-river-threatens-offshore-coral-reefs-2b809e75-5531-162c-e053-0100007-369007911.html

Students supervised who contributed to the project;

Michael Studivan, 2013-present, FAU PhD in Integrative Biology
Jennifer Polinski, 2014-present, FAU MS in Biology
Alycia Shatters, 2014-present, FAU MS in Biology

Extramural funding leveraging SLP resources:
Voss JD, Beal J. Estuarine impacts on coral reef health and the implications for water resource management in Southeast Florida. Florida Sea Grant Program. $144,948. Feb 2014 – Jan 2017

Pending: state legislative request to Sen, Negron coordinated by Martin County. $1.5 million ($1 million to FAU HBOI)

Pending: FWC contract for marine mammal monitoring. ~$14,000

6. Significant findings:

The most important findings from our pilot project underscore the utility and value of UAVs for both science and visual story telling applications. First, in comparing the original DJI Phantom system to the DJI Inspire system purchased through Project CLOUD funds, the new system is dramatically better in terms of resolution, stability, lack of lens distortion, and cinematic flexibility. However, we also determined that no matter which system is used, a substantial amount of time must be dedicated to image postprocessing. For example, lens curvature requires adjustments using image software such as Adobe Photoshop (Figure 1). Batch processing these applications is key to time efficient image and data gathering.

Figure 1. Downward-facing photo taken with the DJI Phantom Vision 2+ before and after lens correction in Adobe Photoshop.

When conducting georeferenced photomosaic procedures, we found that at least 10-20% overlap among images improved the ability of Adobe Photoshop CC to properly align images. We recommend using Photoshop CS6 or newer based on this image merging capability. If sufficient overlap exists, large composite images are possible (Figure 2).

Figure 2. Merged images from a dragline ditch restoration site in the Northern Indian River Lagoon.

Georeferenced composite images are particularly useful to assess landscape scale changes on relatively short timescales (daily, weekly, monthly). Habitat restoration sites are ideal since changes are usually rapid and photographic documentation is frequently a condition for permitting. Using satellite imagery or flyovers are not only more costly, but provide less choice and flexibility with regards to timing, since clouds can be a significant hindrance in Florida. This project was particularly successful when partnering with end users of the data from the outset, such as in our collaboration with FWC to document their salt marsh restoration while simultaneously developing our protocols (Figure 3).

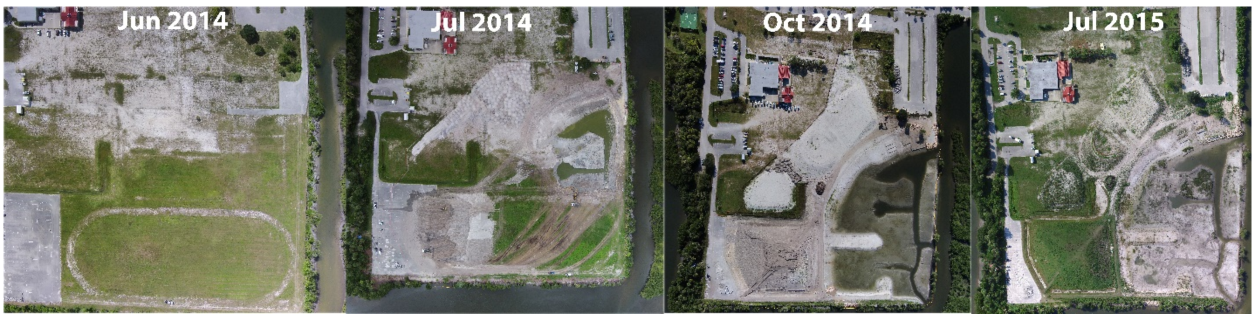

Figure 3. Merged images in time series at the New Smyrna Beach salt marsh restoration FWC project.

Finally, this project underscores the potential society impact of UAV videos as demonstrated through the videos of the St. Lucie Inlet and Lake Okeechobee discharges spreading through the estuary and out over costal coral reefs. With targeted messaging, UAVs can dramatically improve visual storytelling and enhance outreach objectives.

7. Unexpected issues/project changes:

As a result of the DJI Inspire release, we reallocated budget from salaries to expenses in order to purchase this more advanced system. In addition, limitation of time and effort available resulted in a shift in the work toward summer 2015 and a NCE was requested and approved to accommodate this change. While we anticipated a technician working on Project CLOUD, I was not able to recruit and hire an ideal candidate until after we completed the project.

8. Project tasks and progress:

    1. Test the capabilities of the DJI UAV systems in multiple habitats including shallow coral reefs, oyster restoration sites, sea grass restoration sites, marsh restoration sites, and even the HBOI campus will be surveyed. Determine the optimum flight height for generating high resolution data. COMPLETE

2. Integration of multiple software application including DJI's Vision Plus controls, DJI Groundstation, Adobe Photoshop to optimize image collection and processing. COMPLETE
3. Produce no less than 5 high definition videos suitable for outreach and public consumption via the HBOI and Voss Lab websites. In addition the data products generated will be used to enhance scientific presentations, outreach publications, and, when applicable, peer reviewed publications. COMPLETE
4. Best operating practices for using UAV for habitat surveys will be developed as a protocol document. COMPLETE

9. Project Spending:
   Upon recent review of this project account, the PI has determined that not all charges have been properly rectified to this account. The initiation of the TAG was delayed by Workday and charges that were placed on holding indexes have not yet been moved to the TAG. However, with the appropriate charges for the UAV and labor redistributions, the PI estimates that approximately $3000 in unspent funds for technician salary will remain. Once a final amount is determined, these funds may be returned to the Foundation, or they could be reallocated to add additional capabilities to our UAV system in the form of camera filters, extra batteries (they are expensive and short-lived), and an additional tablet controller. Since we are outside the original period of performance, I leave that decision to the Foundation.

Best Operational Practices for UAVs

Last Updated 11/9/15

Collecting and merging landscape images for composite mapping

1. Locate the boundaries of the area to be mapped and determine the optimum number of tacks needed to cover the entire area with a single quadcopter flight.
2. Record the GPS coordinates of at least four landmarks that will be used to georeference the image in post processing.
    a. It is best to use bright colored objects that will stand out from the rest of the background. Blue objects work well on land and yellow objects work well on the water. Avoid using natural landmarks that may move over time.
3. Deploy the quadcopter and ascend to a preset altitude. We find that 400ft allows for sufficient ground coverage and sufficient image quality for mapping.
4. Orient the camera to 90° facing downwards and maintain the same quadcopter heading.
5. Fly a grid pattern over the entire target area (Figure 1), maintaining the same altitude and heading (do not adjust the quadcopter yaw; this requires you to move side-to-side and backwards).
6. Take downward-facing photos along the flight, ensuring complete coverage with overlapping features.

Note: All photos for a particular map need to be taken in the same flight to avoid slight differences in light and ground features.

7. Download all the photos from the target area (Figure 2) onto a computer and open in Adobe Photoshop (CS6 or higher is preferred). Each photo will display as a separate tab.
8. Photos must first be processed to correct lens distortion common on wide-angle quadcopter cameras (Figures 3 and 4). Go to File, Automate, Lens Correction…
9. A window will appear with the lens correction options. Select Add Open Files, set the Destination Folder and File Type as JPG.

Note: The Lens Correction Profile is a quadcopter-specific file that determines the level of lens correction needed. Most commonly used quadcopters have lens correction profiles available online for free.

10. Set the Lens Correction Profile, and select OK.
11. After all the images are done processing, check the destination folder for the corrected versions.
12. Close all existing tabs in Photoshop and then open the corrected images.
13. To merge the images into a single photo, go to File, Automate, Photomerge…
14. Select Add Open Files, then OK. The photomerging process may take several minutes.
15. The finished product will appear as a separate tab. If the process worked completely, you will see a single map. Toggle each layer's visibility in the Layers window to see what part of each photo was used in the final merge.
16. If the area is too large, or contains uniform areas difficult to differentiate from one another, there might be two or more final merges that could not be combined. To fix, try reducing the number of overlapping images, or repeat the photomerging process on the two or more merges.
17. Save the merge tab as a JPG (PNGs usually crash Photoshop as they are so large with merged images).

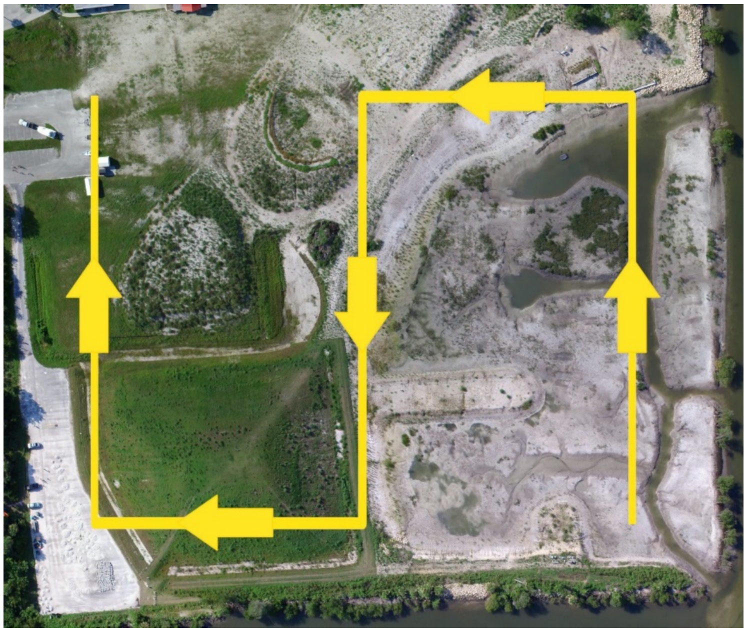

Figure 1. A target area to be mapped, and the grid pattern used to capture all the downward-facing photos. At each 90° turn, the heading of the quadcopter does not change.

Figure 2. A set of overlapping photos taken during the grid pattern flight. These photos were all taken from an altitude of 400ft.

Figure 3. Downward-facing photo taken with the DJI Phantom Vision 2+ before and after lens correction in Adobe Photoshop.

Figure 4. Planar photo taken with the DJI Phantom Vision 2+ before and after lens correction in Adobe Photoshop.

Georeferencing a Photomerged Map

Last Updated 11/10/15

1. Create an Excel spreadsheet using the GPS coordinates of notable landmarks. ArcMap is very specific about naming conventions, so label the two columns as “Easting” and “Northing.” Do not use spaces; instead use “_” in both the file name and in the worksheet.
    a. Coordinates must be in decimal degrees and their respective cells formatted as Number with at least eight decimal places.
2. Open ArcMap 10.x and choose the Blank Map Template. Select Customize, Toolbars, and make sure Georeferencing is checked. If not, selecting it will place the Georeferencing toolbar at the top of ArcMap.
3. Select Add Data (yellow diamond with plus sign). Navigate to your working directory and select the photomerged map file. There will likely be warnings stating Unknown Spatial Reference. Ignore these for now and select OK.
4. Select Add Data again, and navigate to your Excel file, selecting the particular worksheet with the coordinates.
5. Right-click the Excel worksheet in the Table of Contents and select Display XY Data.
6. Make sure the X field reads “Easting” and the Y Field reads “Northing.” Select Edit… to change the coordinate system.
    a. Expand the Geographic Coordinate Systems folder, then World, and select “WGS 1984.”

    b. Select OK at the Display XY Data window and the Object-ID error window.
7. An Event will appear above the Excel worksheet in the Table of Contents. Right-click it and select Data, Export Data…
    a. Keep the options as-is, but change the name of the output shapefile (.shp) to your preference.
    b. Select Yes to add the shapefile to your map as a layer.
8. Right-click and Remove the original Excel file layer (or uncheck it to make it invisible).
9. Double-click the symbol for the new shapefile in the Table of Contents to change its shape, color, and symbol size to make it more visible.
10. To add labels to the GPS coordinates, right-click the shapefile, select Open Attribute Table.
    a. Click the Table Options button, select Add Field.
    b. Give the field a name like "Object_ID" and change the Type to Text.
    c. Go back to the main Arc screen and find the Editor tab at the top toolbar. Select Start Editing, then open the Attribute Table for the shapefile again.
    d. Double-click inside the "Object_ID" field for each point to give it a label.
    e. When all points are labeled, return to the main screen and right-click the shapefile, select Label Features, and select Properties.
    f. Under the Labels tab, change the Label Field to "Object_ID" and select OK.
    g. All points should now be properly labeled.
11. Make sure the photomerged map is selected in the drop-down menu of the Georeferencing toolbar. Zoom out until all the points are filling half of the screen, the select Fit to Display under the Georeferencing drop-down menu. The map will appear over the GPS points.
12. Zoom in to the first landmark in the image and select the Add Control Points button in the toolbar. Click the landmark in the image, then the corresponding GPS point in the shapefile to make the link.
13. Continue to add control points until all the landmarks are linked. The map will autorotate to match the shapefile.
14. Select the View Link Table to check all the landmark links and the residual error between the shapefile and image links.
15. Select Rectify… from the Georeferencing drop-down menu. Leave the Cell Size as is, but change the NoData as to blank. Navigate to your working directory for the Output Location and set a name. Set the Format as TIFF. Select OK.
16. The georeferenced TIFF will be saved with several other similarly named filetypes and is now ready for any additional analyses.

Altitude Considerations

In the protocol development stage of the photomerging process, we tested the effectiveness of taking downward-facing photos at different altitudes in capturing sufficient resolution for mapping. Recreational drones are altitude-limited to 400ft, therefore we tested a range between 100-400ft. Flights below 100ft for mapping should be avoided to prevent the chance of the quadcopter striking buildings, trees, and utility lines. Figure 5 shows two different photos of the same target site taken at 100ft and 400ft, respectively. The zoomed cutout shows the same area in both photos magnified to the same size. While images taken at 100ft give slightly more image resolution and detail, 400ft flights are logistically simpler and require fewer images to capture a larger target area. Consideration for flight altitude should be made depending on the size of the area to be mapped and the resolution required for downstream quantitative analyses. For example, to measure the area covered by salt marsh habitat or seagrass beds, a higher altitude would be sufficient, while a lower flight would be required in order to count individual plants within the above habitats.

Figure 5. Downward-facing photos taken of the same target at 100ft and 400ft, respectively. The cutout shows a set area blown up to the same size for image resolution comparison.

Pitfalls and Limitations

- Drone registration required by law as of Dec 21, 2015 https://www.faa.gov/uas/registration/
- 400ft altitude restriction
- 5 mile no-fly zone round active airports
- No-fly zones in FL state parks
- Flight restrictions on federal vessels
- Loss of control and GPS station-holding with high winds
- Lithium ion battery management
- Magnetic interference on vessels

Suggestions and Considerations

- Dedicate two people to fly (one pilot, one videographer/catcher)
- Do not push the battery below 30% to ensure proper recovery
- When recording video, move deliberately and slowly
    - Avoid quadcopter yaw (use camera yaw instead)
- Format the onboard SD card before each flight via the DJI GO app
- Avoid large changes in camera pitch to avoid lens warping
- Take multiple photos and video of the same target
- When mapping, take photos of the surrounding area outside the target site as well
- Use Attitude mode when there are constant velocity and direction winds for smooth tracking video
- Consider hard drive space requirements of 4K video
- Record a mix of stationary and moving video for variability in the finished product
- If not using the quadcopter for a week or more, discharge the batteries by leaving the quadcopter on without props spinning
- Likewise, if preparing to use the quadcopter after a period of non-use, run the batteries for several minutes, then recharge. The LED battery indicators may show 100%, but when flying, the battery level will quickly drop 30-50% in the first minutes of flight.