



RHODE ISLAND CONSORTIUM FOR
Coastal Ecology
Assessment
Innovation &
Modeling

Drones and the Bay

Detecting Wave Velocity Fields using UAS

Determining the Largest Wave Velocities in the Bay

ELECOMP Capstone Design Project 2020-2021

Sponsoring Company:

RI NSF EPSCoR

Graduate School of Oceanography

URI Bay Campus

215 South Ferry Road

Narragansett, RI 02882

Company Overview:

Funded by a \$19 million National Science Foundation grant and a \$3.8 million state match, RI C-AIM is a collaboration of engineers, scientists, designers and communicators from [eight higher education institutions](#) developing new approaches to assess, predict and respond to the effects of climate change on coastal ecosystems.



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Project Motivation:

The Fox-Kemper Research group at Brown University is working to model the Narragansett Bay to Block Island Sound, Martha's Vineyard, Fishers Island and up into the estuaries of the Providence River. The goal of their research is to create the OSOM (Ocean State Ocean Model), a computer model which takes into account all parts of the bay to show the past and present of how the bay is changing. Once the OSOM's predictability is better, it will be used to show how the bay is changing over time. The overarching goal is for the OSOM to be able to accurately predict changes in climate of the bay over years and decades and weather changes up to 2 weeks in the future. Scientists working for Baylor and other research groups have analyzed variables including salinity, water density, water pressure, chlorophyll, bacteria growth, algae bloom frequency, spectral reflectance and wave velocity fields in order to help model the Narragansett Bay and the inner coastal shelf.

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Drone modeling of the bay is another way that scientists can obtain data, and as of now it has not been possible to get wave velocity data using a drone. Wave velocity data from the drone will be used to calibrate the OSOM data that has already been collected. The Fox-Kemper Research Group has used satellites, buoys, drifters and acoustic doppler current profilers (ADCPs) to obtain wave field velocity data, but none of these methods has the accuracy of a drone. Satellite data is taken every few weeks depending on a satellite's orbital path. Buoy data is taken at the surface of the water or the top few feet. Drifter data can be taken at a particular depth, but they are unable to be controlled, which makes them inexpensive, but ineffective. At this point in time ADCPs are the most accurate way to measure ocean currents because an ADCP is maneuvered using a ship and can measure deeper and more accurate than most other means of measurement. Using drone modeling, scientists hope to be able to accurately measure ocean currents for much cheaper than what was previously possible, with the control and accuracy of GPS.

Using a drone will allow researchers the ability to program waypoints so they can measure currents where they would like, the DJI Mavic line of drones which will be used for this project, will allow scientists to define exactly what spatial orientation, height and GPS coordinates they would like fly with an accuracy down to about .5 m. This will allow scientists the freedom to get the most accurate data possible. The wave velocity field data acquired by the drone will be compared to the OSOM data in order to verify accuracy of the model and calibrate the data of the model.

Hydroelectric turbines are commonly used to create power at the mouth of lakes and estuaries, Dr. Baylor Fox-Kemper has been looking to install hydroelectric turbines in Narragansett Bay, in order to effectively pinpoint where the turbines will be placed, wave velocity field data must be taken from multiple places in the bay. These velocity measurements will be used to determine where in the bay the turbine will produce the most power. The long term goal of this project is to aid Dr. Fox-Kemper in positioning hydroelectric turbines,



Anticipated Best Outcome:

The anticipated best outcome is to obtain a fully functional program using MATLAB which is able to measure wave velocity fields and create a velocity gradient map for each video taken with the drone. An array will also be created showing the average area velocity of multiple pixels on each video. Instruction will also be created along with MATLAB files so the project can easily be adapted by other users, the instructions will include weather conditions, ocean conditions and correct drone flying to obtain the most accurate wave velocities. Should all of these outcomes be accomplished, further steps will be taken to find the current fields throughout Narragansett Bay with the largest magnitudes, this will help Baylor in his goals in finding where to place hydroelectric turbines.

Project Details:

A clear picture of the concept is obtained by reading the following articles:

<https://www.cmre.nato.int/msaw-2019-home/msaw2019-papers/1362-msaw2019-horstmanncoptercurrentshighresolutionsurfacecurrentfieldsmeasuredbyasmalluav/file>

The concept of the project is to continue the work mentioned in the article. The team will start by adapting the MATLAB code from the GITHUB repository to work seamlessly with an example video. As of now, numerous errors have been found when using the current code to analyze flight footage.

The team will then choose which drone will give them the most accurate wave velocities and the clearest image, giving preference to DJI due to original code intentions. The team should explore different options and find a drone which is inexpensive, has many options for camera settings and is able to sufficiently record wave velocities (keep in mind, the wavelength of each gravitational ocean wave will be a minimum of .3m). The team will need to research which camera will give them the most accurate data and which of the following is most important for this application: shutter speed, ISO, aperture, camera resolution, camera frame rate.

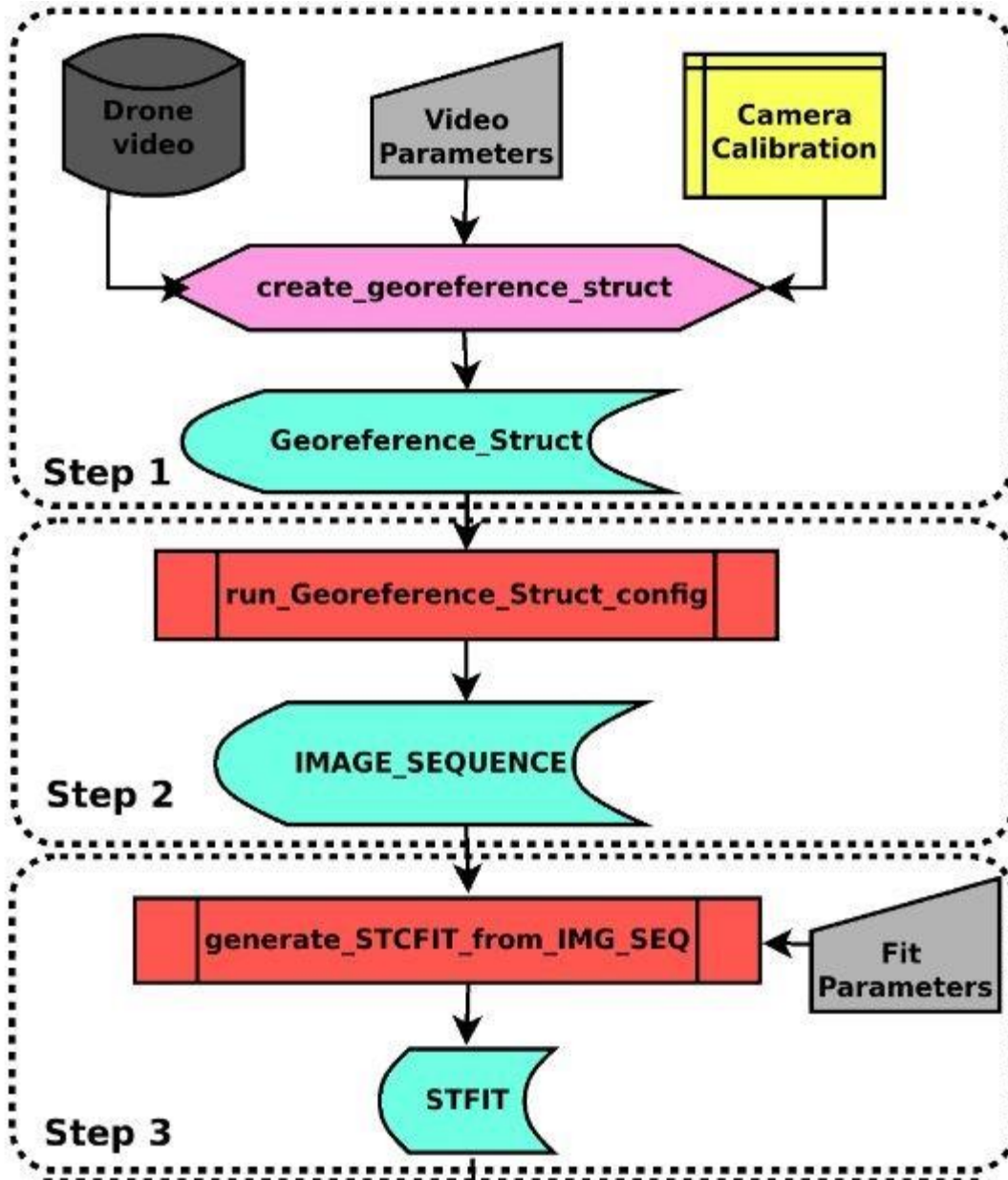
The next step is to be able to analyze flight footage taken with the team's drone. Ideally, the user should be able to insert their own camera footage and camera parameters using a GUI or another

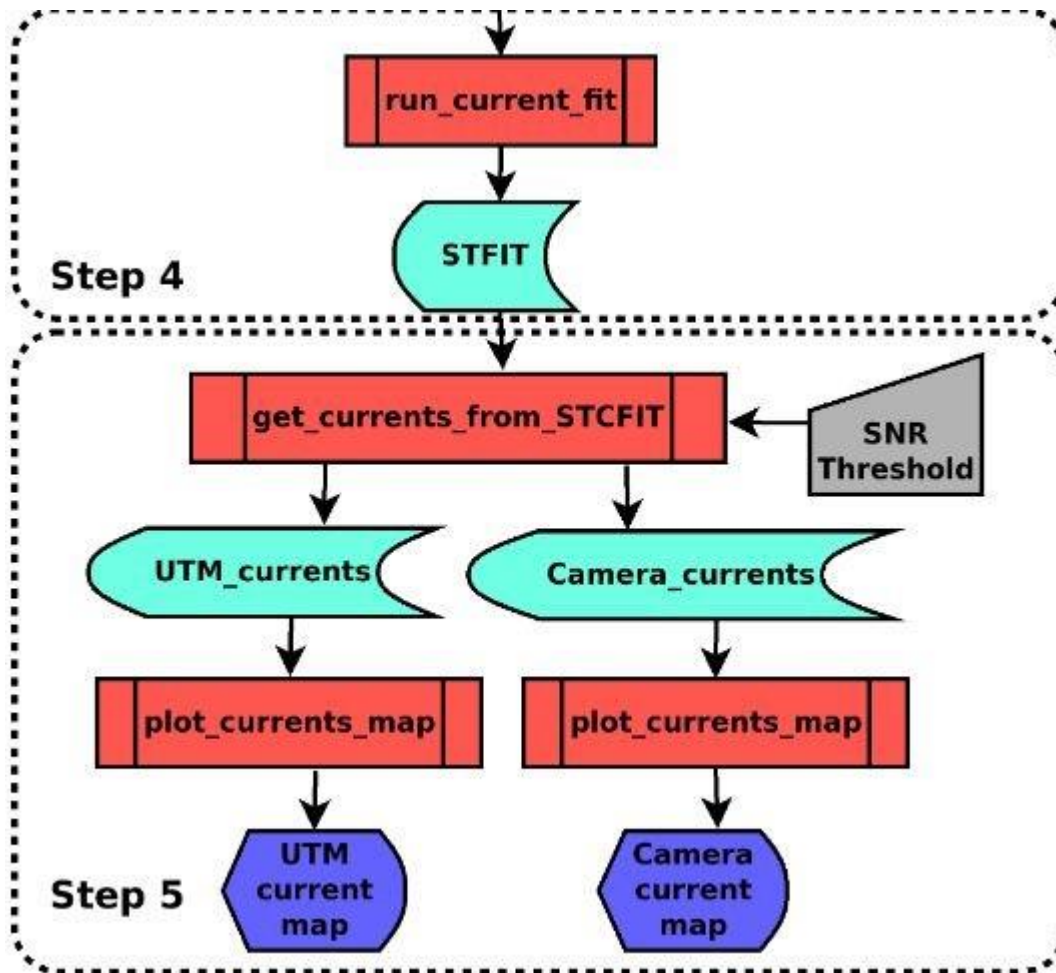


unobscure way to tell the user to input their parameters. The goal is for the user to be focused on the data as much as possible rather than fiddling with code.

After the MATLAB code is up and running, the team will start their experimentation by taking drone footage of several points in the bay at various temperatures, wind speeds and times during each diurnal tide to see what conditions give the most accurate data and which variables are the most important in determining wave velocity fields. The team will use waypoints to improve the accuracy of their footage when evaluating the best flying conditions.

Furthermore, if each of these goals is to be reached, the data attained by the drone will aid researchers at the Fox-Kemper research group in calibrating and verifying velocity data of the OSOM model. Upon reaching these goals, the team will determine where throughout Narragansett Bay the wave velocity fields are the greatest. Once the code is working, instructions will be written with the intention that an unfamiliar user can easily install the program and analyze a video within 1 day's work. Everything will be documented for further use by other scientists and researchers.







Electrical Tasks:

- All students must perform research so that they have a comprehensive understanding of MATLAB; understanding file directories, function definitions and executions are a must: [Comprehensive MATLAB Tutorial](#)

1 student will focus on knowledge of the drone, determining the best flying conditions for the drone and determining which drone will be best for the project. (This student task is already assigned). This student's tasks include:

- Research and determine the correct drone for performing the necessary tasks, evaluating factors such as:
 - Shutter speed
 - Lens aperture
 - Frame rate
- Work on programming the drone to fly using GPS so that multiple trials may be done in the same location

1 student will focus on their knowledge of MATLAB to analyze the flight footage and ensure that the data is correct. This student's tasks include:

- Make comparisons of the data to the OSOM data
- Research power spectrum analysis and fourier analysis in regards to ocean currents
- Understand signal processing using fourier transforms; students will research this topic

1 student will focus their knowledge on the geological conditions of the bay and determine which parts of the bay have the best conditions to take velocity data, there tasks also include the following:

- Research and determine the best geological conditions for obtaining flight footage
- Research which conditions lead to the most accurate current measurements
- Determine which part of the bay has the highest current fields



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Composition of Team:

3 Electrical Engineers (ELE)

Preference will be given to students who have completed the MATLAB tutorial, students with a biology background, an interest in biology or previous use of drones either in a job or as a hobby. Students need to have a comprehensive understanding of Python or MATLAB as these two programming languages are similar and the majority of the work performed during the year will be using MATLAB.

Skills Required:

Electrical Engineering Skills Required:

- Proficiency in MATLAB and Python: Students should have experience using structure fields, heavy knowledge of MATLAB file directories, experience using function and executing functions. A heavy understanding of MATLAB is vital.
- Linear systems and signal processing: Parallel computing
- Image processing
- Reading and understanding research papers

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

Should the outcome be determined a success, footage taken using a drone should be able to be accurately analysed within .1 m/s to determine surface currents throughout Narragansett Bay. Should the project succeed, the currents in Narragansett Bay will be used to evaluate the accuracy of OSOM and any inaccuracies in OSOM data will be corrected by the drone. The drone data will also be used to determine where underwater turbines are to be placed throughout the Bay.

Broader Implications of the Best Outcome on the Company's Industry:

Should the project succeed, a successful drone mapping of parts of the bay will lead the way towards inexpensive research on Narragansett Bay. Currently most velocity mapping is performed with satellites, drifters or radar using a boat, but the mapping of the bay using a drone will allow researchers to get velocity data more accurately and quickly than in previous years. Drone mapping is the cheapest way to gain valuable data and is also much quicker than any other form of velocity measurement thus far.