Introduction

- Submarine groundwater discharge (SGD) is an essential source of land-derived nutrients for coastal waters, but excess anthropogenic nutrient loading (e.g. from agriculture or cesspools) can significantly degrade coastal ecosystems.
- Groundwater is insulated from the sun, so temperature gradients exist between discharging groundwater and receiving surface water bodies. These temperature differences are easily detectable by thermal infrared (TIR) imaging.
- Recent studies have utilized aircraft and/or ground-based TIR to survey coastal areas, estuaries, and rivers/streams for groundwater inputs. However, these methods have significant limitations, as Aircraft-TIR can be limited by cloud cover, and ground-based TIR is impractical for surveying large areas.
- UAV-TIR is ideal for surveying SGD on a small scale because it allows unprecedented data collection flexibility and high-resolution below-cloud TIR imaging.

Goals

- Identify locations of submarine groundwater discharge in Central Kāne‘ohe Bay, based on thermal contrast between groundwater and surface water.
- Previous studies (Lee et al., 2016; Kennedy et al., 2017) utilized UAV-TIR as a follow-up to Aircraft-TIR studies. The goal of this study is to demonstrate effective independent use of UAV-TIR for locating and mapping SGD.

Methods

Equipment

<table>
<thead>
<tr>
<th>UAV Platform</th>
<th>3DR X8+ Octocopter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>14.8V Lithium Polymer batteries</td>
</tr>
<tr>
<td>Autopilot</td>
<td>Pixhawk</td>
</tr>
<tr>
<td>TIR Camera</td>
<td>FLIR Tau 2 640</td>
</tr>
<tr>
<td>Focal Length</td>
<td>13 mm</td>
</tr>
<tr>
<td>Pixel Resolution</td>
<td>0.2 m</td>
</tr>
<tr>
<td>Temperature Resolution</td>
<td>0.04° C</td>
</tr>
<tr>
<td>Image Capture</td>
<td>TeAx Thermal Capture</td>
</tr>
</tbody>
</table>

Data Collection

- 10-12 minute flights, 120 meter altitude
- Flights conducted during low tide to maximize hydraulic gradients, and late in the day to maximize thermal gradients
- In-situ thermistors deployed during flights to ground-truth TIR data
- Thermal imagery collected at a rate of 9 Hz (9 frames per second)
- Spatial data attached to each image via on-board GPS unit
- Data relayed to ground station monitor for real-time analysis

Post-Processing

- ThermoViewer – raw thermal files converted to grayscale JPEGs
- Adobe Lightroom – vignette corrections applied to grayscale JPEGs
- Microsoft ICE – image mosaicking with corrected grayscale JPEGs
- ArcGIS – grayscale mosaics converted to temperature rasters
- Data relayed to ground station monitor for real-time analysis

Conclusions / Future Work

The use of UAV-TIR in Kāne‘ohe Bay has allowed us to easily locate submarine groundwater discharge, identify the areal extent of SGD, distinguish between point-source and diffuse discharge, and quantify temperature gradients. UAV-TIR is a flexible and cost-effective tool for mapping and monitoring SGD, independent of Aerial-TIR surveys.

Future Work

- Map the entire Central Kāne‘ohe Bay coastline
- Follow-up geochemical studies to characterize SGD
- Apply these methods to detect stream baseflow

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