**GPS Drifter: Continuity Report**

Team Drift Away

Steven Anderson, Cole Argay, Maya Leighton, Ben Middour

OCN479/GEO592: Smart Coasts

11 December 2024

**Table of Contents**

1. **Introduction and Background**
2. **Methods**
   1. Starting Point and Goals
   2. Code
   3. System
      1. Hardware
         1. GPS Module Specifications
      2. Function
   4. Drifter
3. **Results and Status**
   1. Battery Test
   2. GPS Test
   3. Drifter Float Test
   4. Summary of Current Status and Limitations
4. **Next Steps**
   1. Future Work
   2. Challenges Faced and Learning Experiences
   3. Recommendations for Incoming Students
5. **Introduction and Background**

Oceanic surface drifters are commonly applied oceanographic tools used to collect data regarding surface currents, temperature, salinity, and other environmental parameters. These drifters float on the ocean surface and are typically equipped with a GPS transmitter to record and notify researchers of the location of the drifter over time. By simply tracking the movement of these drifters, researchers can estimate and map circulation patterns in the open ocean, nearshore locations, and a wide variety of basins (LaCasce, 2008).

For our purpose, we focus on the application of a GPS-tracked drifter to be deployed in the nearshore, specifically a semi-enclosed basin that empties into a system of tidal creeks and waterways. In the nearshore environment, GPS-tracked drifters may be used to study circulation patterns, dispersion processes, and residence/flushing times. These characteristics are crucial in understanding water movement and the transport of materials. By tracking the paths of GPS-tracked surface drifters, the dispersion of nutrients, sediments, and pollutants in oceanic systems can be estimated and analyzed. This information is crucial for efficiently addressing issues such as pollutant dispersal, such as oil spills, managing coastal ecosystems, as well as coastal engineering applications (Pawlowicz et al., 2019). Observations from GPS-tracked oceanic surface drifters can also be used to validate and increase the accuracy of numerical model outputs (Taherkhani et al., 2023).

The process of designing and deploying a GPS-tracked drifter begins with defining the purpose of the drifter, such as studying circulation patterns, dispersion, or a variety of other parameters. The drifter’s design should include a robust waterproof housing to protect the electronics or ‘brain’ of the system. The GPS unit should provide accurate and precise real-time positioning and be integrated with a telemetry system (Wi-Fi, cellular, satellite) for location transmission and be optimized for low power consumption.

1. **Methods**
   1. **Starting Point and Goals**

We had a sufficient starting point for this project. Initial code for depth, temperature, and GPS sensors; a hardware system used for depth and GPS functions; and a drifter structure from a previous project were provided to us. Our goal was to improve upon what we were given and adapt what we had to the purpose of our drifter with GPS and cellular capability. This included cleaning up and modifying the code to fit only the GPS functions; testing the power source; removing extra components and attaching cellular components for the hardware; and refining the drifter design to incorporate functional and protective casing for the hardware and improving its floatability. The sections below detail our methods.

* 1. **Code**

Code from *SUPScientist / smart-coasts-bathy-mapping* GitHub Repository (https://github.com/SUPScientist/smart-coasts-bathy-mapping) was provided by Dr. Bresnahan (depth-sensing-ping-SD-GPS-temp.cpp). The Repository was forked (our repository: https://github.com/mayaleighton/smart-coasts-bathy-mapping), and the code was modified in Visual Studio Code 2.

The initial code was developed for a GPS-tracked drifter with peripheral sensors, including depth and temperature. In brief, the code started with void setup (), where the GPS and update rate were set, and the SD library was initialized. The main section of the code (void loop()) called in serialPrintGPSTime() and if(GPS.fix), then serialPrintGPSLoc() (which means that if the GPS gets a fix, the output will be printed); and defined temperatureC = getTemp() and depth = getDepth(temperatureC). Get depth and temperature and print to SD card functions proceeded. The print to SD card function included date, time, elapsed time, location, temperature, depth/distance, altitude, angle, GPS time, and GPS location.

The depth and temperature functions were unnecessary for our drifter’s purpose, so the code was first trimmed down to only include the GPS-related functions. The code functioned the same minus the depth and temperature functions: void setup () initializes GPS, update rate, and SD library; void loop () calls in serialPrintGPSTime(), if(GPS.fix), then serialPrintGPSLoc(), and the print to SD card function. In addition to this, a chunk of code for cellular connectivity was added. However, we did not get it a point where it was functional and an account was not linked to our code, so the cellular code chunk remained inactive (commented out). Date, time, elapsed time, location, altitude and angle were printed to the SD card. Latitude and longitude were recorded as DDMM.MMMM (E.g., 3408.5590 N 7752.0597 W) (see section 3.2 for a description of how coordinates were converted to a readable format). Altogether, the current code flashes successfully.

* 1. **System**
     1. **Hardware**

The system’s hardware consists of a cellular device, datalogger with a micro-SD card, GPS unit, power source and cellular antenna (Table 1). Originally, the hardware had a depth sensor attached; this was desoldered.

|  |  |
| --- | --- |
| **Table 1.** Components of system hardware. | |
| Cellular Device | *Particle* Boron |
| Datalogger | *Adafruit* Feather M0 Adalogger |
| GPS Unit | *Adafruit* Ultimate GPS FeatherWing w/ Ultimate GPS Module PA1616D |
| Power Source | External battery: 3.7 V Rechargeable LiPO Battery |
| Cellular Antenna | *Particle* Wide Band Antenna |

The GPS unit (A), Adalogger (B), and *Particle* Boron (C) (Figure 1) were stacked on a tripler (Figure 1) to integrate the different components. The external battery (Figure 2) was plugged into the *Particle* Boron. It is important to note that the power source can vary depending on one’s project/research goal. The micro-SD card was inserted into the Adalogger. The *Particle* Wide Band Antenna was not attached during this project. The circuit diagram (Figure 3) shows the system’s electrical set-up.

|  |
| --- |
| A group of electronic components  Description automatically generated |
| **Figure 1.** Image of hardware setup: **A)** GPS unit, **B)** Adalogger, and **C)** *Particle* Boron. |

|  |
| --- |
| A blue battery with black and red wires  Description automatically generated |
| **Figure 2.** Battery used (see Table 1). |

|  |
| --- |
| A diagram of a computer  Description automatically generated |
| **Figure 3.** Circuit diagram of the hardware setup including the GPS unit (GPS), *Particle* Boron (Boron LTE), and Adalogger. Made in Microsoft ® PowerPoint. |

* + - 1. **GPS Module Specifications**

|  |  |
| --- | --- |
| **Table 2.** *Adafruit* Ultimate GPS Module PA1616D specifications from *CD-PA1616D GNSS patch antenna module Data Sheet V.05* (see references). Specifications selected for drifter purpose. Terms defined below. | |
| Operating Frequency | GPS L1: 1575.42 MHz  GLONASS L1: 1598.0625 – 1605.375 MHz |
| GPS Sensitivity | Acquisition: -148 dBm |
| Update Rate | 1 – 10 Hz |
| Baud Rate | 9600 bps |
| Position Accuracy | < 3 m |
| Maximum Velocity | 515 m/s (1000 kts) |
| Power Supply | VCC: 3.0 – 4.3 V  VBACKUP: 2.0 – 4.3 V |
| Current Consumption (at 3.3 V, 1 Hz Update Rate) | Acquisition: 34 mA  Tracking: 29 m A |

* **Operating frequency:** frequency at which the GPS module receives a signal from a satellite (measured in MHz; unit of frequency).
  + **GPS L1:** type of GPS signal.
  + **GLONASS:** Global Navigation Satellite System.
* **GPS Sensitivity:** how well a GPS module can detect a weak satellite signal (measured in decibel-milliwatts; unit of power).
  + **Acquisition Sensitivity:** detect and fix onto a satellite signal for the first time or after losing a signal.
* **Update Rate:** how often a GPS module updates its position (measured in Hz; unit of frequency).
* **Baud Rate:** the speed at which data is transmitted from a GPS module (measured in bits per second).
* **Position Accuracy:** how closely a GPS module’s calculated position matches its actual location (measured in meters).
* **Maximum Velocity:** fastest speed at which a GPS module can accurately track its location (measured in meters per second).
* **Power Supply:** voltage required to power a GPS module (measured in volts).
* **Current Consumption:** amount of current the GPS module uses when it is operating (measured in milliamps).

No information was found about precision. This can come from an improved GPS test (outlined in section 4.1).

* + 1. **Function**

An overview of how our system works is detailed below. Note that this is how it should work ideally; our cellular connectivity code was inactive (see section 2.2).

1. *Particle* Boron should connect to a satellite via the cellular antenna.
   1. This would allow for the transmission of the drifter’s location. However, this is not active in our code.
2. Once the GPS unit receives a fix on >1 satellites, location is received by the GPS unit.
3. The GPS unit processes the signal and generates coordinates of the drifter’s position.
4. This is printed/stored on the micro-SD card.
   1. Location is also transmitted to shore via the cellular signal at lower frequency.

For this project, the GPS unit was able to successfully achieve a fix on one or many satellites to provide a location, however the *Particle* Boron was never able to successfully communicate with a satellite to transmit the location via cellular connectivity.

* 1. **Drifter**

The surface drifter consists of four essential sections: a vertical body, a rectangular frame with pool noodles, wings at the base, and a Pelican Case (Figure 4). A previous research project constructed this physical structure. The configuration of this design was determined sufficient, and structural changes were not undertaken for this project. However, the previous project installed a 4” PVC opening in the vertical body that served as an access to the hardware housed inside. In the original project, this opening would have been sealed with an end cap before deployment. Modifying this opening was not pursued due to time restraints and ultimately considered a lower priority for this project considering that hardware is not housed inside the vertical body. Additionally, a Pelican 1050 Micro Case that was used for a previous research project was provided for this project. This Pelican Case has a small opening on the side of the case. Sealing this opening is considered a high priority before deployment to ensure the hardware is not compromised by intruding water.

The body of the drifter is the central structure, consisting of 4” PVC pipe with a vertical height of 29”. This section provides support for all other components and ensures durability during deployment. Extending perpendicularly from the body are 1” PVC pipes arranged to form a rectangular plane with a 21.3” perimeter. This rectangular frame is assembled by 90° PVC elbows at each corner and two equal tee PVC pipes that attach the frame to the body of the drifter (Figure 4B). To ensure buoyancy, pool noodles are attached along the 1” PVC of the rectangular frame. These cylindrical and lightweight foam pool noodles are the primary component that ensures the drifter stays afloat in water. At the base of the drifter, 6.1”x12” wings are attached to support stability and minimize the influence of wind or surface turbulence. These wings help the drifter more accurately align with flow dynamics during deployment.

An 8.4”x5” Pelican Case is used to house the electronic hardware due to its high-impact and watertight plastic material. This housing is secured by zip ties attached to the pool noodles that cover the 1” PVC. To ensure and maintain optimal cellular connectivity, the Pelican Case is mounted at the top of the drifter and elevated above the water line. Keeping the hardware above water minimizes uninterrupted cellular data transmission and the watertight Pelican Case protects the hardware from moisture and wave splash.

|  |
| --- |
| **A drawing of a pipe  Description automatically generated**  **A)** |
| A drawing of a rectangular object with red lines  Description automatically generated  **B)** |
| **Figure 4.** Schematic of the physical structure of the surface drifter: **A)** side view and **B)** top view. Measurements in inches; not to scale (NTS). Drawn in a gridded notebook with GoodNotes 5 version 6.5.17. |
| **A white object with a blue box on top of green foam tubes  Description automatically generated with medium confidence**  **A)** |
| **A pool noodle holder with foamy handles  Description automatically generated with medium confidence**  **B)** |
| **Figure 5.** Images of the surface drifter: **A)** body and **B)** top with Pelican Case. |

1. **Results and Status**
   1. **Battery Test**

We attempted to conduct a simple battery test to analyze the power consumption and battery life of the system when powered by an external 3.7 V rechargeable LiPO battery. The system was flashed with the (at the time) updated code and was set up to run in a location where the GPS unit could successfully achieve a fix on a satellite and was left to run until it died. The battery life and power consumption would be evaluated by the timestamps of the first and last location entry. The system was left to run, logging the location at a frequency of 1 Hz to the SD card onboard. It ran for one week and did not die in time before the system was needed for the next class period, so we were unable to successfully evaluate battery life and power consumption. This test could be heavily improved upon (outlined in section 4.1).

* 1. **GPS Test**

As we did not have time to conduct a deployment test for our GPS-tracked drifter in an oceanic environment, we conducted a test of the GPS system by walking around the Center for Marine Science (CMS) parking lot while the system was running on an external battery (Figure 6).

|  |
| --- |
|  |
| **Figure 6.** MATLAB Geoscatter plotting function used to display locations from GPS unit logged to the system’s SD card. |

However, this test was not verified against another source of locations other than those from our system and knowing the path walked during the test. This is a major shortcoming in our plan to validate the positions from our system, and suggestions for improvement are outlined in section 4.1.

The locations from the GPS were printed to the system’s SD card in the format DDMM.MMMM, where D denotes degree ‘decimal’ format and M denotes ‘minute’. This format is not one that can be easily interpreted with software used to visualize location data. To properly format the locations, a MATLAB script was developed to convert the locations into ‘decimal degree’ format (ex. 34.2104° N, 77.8868° W). The locations could then be easily visualized using MATLAB’s ‘Mapping Toolbox’ (Geoscatter function).

* 1. **Drifter Float Test**

The drifter was tested once at the CMS dock, in the Intracoastal Waterway, to evaluate its buoyancy (Figure 7). This test involved attaching a rope to the drifter and lowering it into the water surrounding the dock. This controlled experiment allowed us to monitor the drifter’s performance in an environment with minimal fluvial influences. The drifter floated steadily on the water surface, proving that the pool noodles provided sufficient buoyancy.

|  |
| --- |
| **A device with green foam sticks floating in water  Description automatically generated with medium confidence** |
| **Figure 7.** Image of drifter deployment off the CMS dock. |

* 1. **Summary of Current Status and Limitations**

The status of our drifter is as follows: the drifter floats (see section 3.3); our system works (see section 2.3.2), and code mostly works (see sections 2.2 and 2.3.2), based on our successful GPS test run (see section 3.2); and we have a way to convert the recorded coordinates to a readable format to interpret the data (see section 3.2).

Despite the status, there are still limitations. The first limitation is the battery life. Battery life limits the functionality of our drifter as the system runs on an external battery. When the battery voltage reaches a low enough voltage, the system will die and no longer be able to log the location of the drifter. The next limitation is the GPS signal. GPS signal strength is highly variable depending on several factors. These include the number of satellites the GPS unit achieves a fix upon, the strength of these fixes, and a wide range of environmental parameters such as atmospheric conditions, obstructions (urban development, vegetation, terrain), weather conditions, and satellite geometry. Furthermore, the cellular connectivity code is not functional and is inactive in our code (see sections 2.2 and 2.3.2); the cellular antenna is also not attached. Lastly, the drifter in its current design may be vulnerable to wind and wave activity. Further testing needs to be done to ensure its stability and durability under various conditions.

1. **Next Steps**
   1. **Future Work**

The greatest improvement to the system would be to finish the integration of cellular telemetry into the system, which would allow for the periodic transmission of the drifter’s location remotely. This is a crucial component to the system as this allows users to know where the drifter is and aid in the recovery of the drifter. Recovery of the drifter in our case is crucial as the data to be analyzed is being stored on the SD card onboard the drifter. This would also include attaching the cellular antenna.

The battery test could be improved upon by having the system log the battery voltage from the external battery to the SD card so we can see the evolution of the battery voltage over time. This would allow for greater analysis of the power consumption of the system. It is very important to note that the cellular telemetry capability of the system was not active at the time our test was conducted. This is the most power-hungry function of the system and should be active during any future test of battery life to obtain an accurate understanding of the power consumption of the system.

The testing of the GPS unit could also be significantly improved upon. This could be done by comparing the locations obtained by our system with those obtained via an expensive, validated GPS system such as Real-Time Kinematics (RTK) GPS. These RTK systems, as well as others, provide extremely accurate and precise locations and would be suitable for analyzing the accuracy of the locations from our system. Statistical analysis could also be done to truly analyze the difference between the locations provided by our system and those from an established, verified GPS system. Further to this, as no specification information was found about precision, measurements of precision can come from an improved GPS test.

Future steps for drifter design involve several critical steps before deployment. First, the Pelican Case must be sealed to prevent water intrusion and ensure the housed electronic hardware is protected. This step is a high priority, as any compromise to the case’s integrity could cause malfunctions in software performance. Second, the opening in the 4” PVC on the vertical body allows water to enter and fill the interior when submerged. This opening could be beneficial in ensuring the drifter remains buoyant. However, water within the interior could negatively affect the flow dynamics of the drifter during deployment.

Further assessments are needed to determine the utility of having this opening along the vertical body. Conducting field tests in different environments is ideal for evaluating how the 4” PVC opening affects performance. Testing in tidal creeks allows for observation of the drifters’ response to slower currents with shallow and fluctuating water levels. Trails in the Cape Fear River reveal performance on the drifters’ ability to withstand a stronger and more consistent current. Lastly, testing the drifter in the ocean will assess its durability and functionality in larger waves and wind-driven turbulence.

* 1. **Challenges Faced and Lessons Learned**

Some specific hurdles we had to overcome were producing the proper code to make our sensors function as well as adapting our drifter to be suitable for field research. The code was challenging to work with at first because of some knowledge gaps and took some time to get familiar with, specifically the cellular connectivity code. There was a lot of trial and error at first but taking the time to look through the code and refer to online resources and other example code files led to code that flashed successfully (even though it needs more work). In addition to this, although we were given a premade base for our drifter, we did have to make modifications to accommodate the water level and sensor stability. We overcame these challenges through creativity and collaboration and engineering a proper mount with zip ties cross-tied with each other to ensure the proper stability of our Pelican Case, which held our sensors in a secure way.

Overcome these challenges took teamwork and utilizing our resources, whether online or in the lab. We all spent time researching and modifying code or about a mount for our sensor or testing materials to improve the drifter. Overcoming these challenges, led to a lot of success during this project. Overall, others can learn from our experience by troubleshooting the code in its entirety before testing the drifter to fully demonstrate the drifter’s capability.

* 1. **Recommendations for Incoming Students**

This class may seem intimating at first, but if you come in with a positive attitude, open mind, and willingness to engage, you’ll leave having gained valuable new skills and knowledge. Even though you may struggle at first, don’t give up. Apply yourself during the lab exercises (they really help further down the line!) and ask questions! Remember that this class, and science in general, is about exploring, discovering, learning, and real-world applications. Embrace the process and listen to Dr. Bresnahan’s words “Progress, not perfection!”

For this project, start with this report. Sections 3 and 4.1 outline the current status and limitations, and future work for our drifter. In addition to this, review our GitHub repository (linked in section 2.2). The repository includes this report, relevant figures, and the code (both the previous code and our code).

**References**

*Adafruit Ultimate GPS FeatherWing*. (n.d.). Adafruit Industries. https://www.adafruit.com/product/3133.

CD Technology. *CD-PA1616D GNSS patch antenna module Data Sheet V.05*. https://cdn-shop.adafruit.com/product-files/5186/5186\_PA1616D\_Datasheet.pdf.

LaCasce, J. H. (2008). Statistics from Lagrangian observations. *Progress in Oceanography, 77*(1), 1-29. https://doi.org/10.1016/j.pocean.2008.02.002.

Lady ada. (2015, December 09). *Adafruit Feather M0 Adalogger*. Adafruit Industries. https://learn.adafruit.com/adafruit-feather-m0-adalogger/overview.

Lady ada. (2016, May 17). *Adafruit Ultimate GPS Featherwing*. Adafruit Industries. https://learn.adafruit.com/adafruit-ultimate-gps-featherwing/overview.

Pawlowicz, R., Hannah, C., & Rosenberger, A. (2019). Lagrangian observations of estuarine residence times, dispersion, and trapping in the Salish Sea. *Estuarine Coastal and Shelf Science, 225*, 106246. https://doi.org/10.1016/j.ecss.2019.106246.

Schmidt, W. E., Woodward, B. T., Millikan, K. S., et al. (2003). A GPS-Tracked Surf Zone Drifter. *Journal of Atmospheric and Oceanic Technology, 20*(7), 1069-1075. https://doi.org/10.1175/1460.1.

Taherkhani, M., Vitousek, S., Walter, R. K., O'Leary, J., & Khodadoust, A. P. (2023). Flushing time variability in a short, low-inflow estuary. *Estuarine, Coastal and Shelf Science*, *284*, 108277.