Glider Guidance System White Paper

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Introduction

Background

Autonomous underwater vehicles (AUVs, which are also synonymous with the term gliders), are advanced oceanographic sampling instruments which are capable of being deployed anywhere in the ocean and conducting remote sensing data collection operations. Gliders are capable of being extremely energy efficient by utilizing Archimedes principle to convert autonomous density changes (which are driven by an on-board buoyancy pump) into forward momentum as it moves up and down in the water column.(1) Navigating these gliders effectively though strong and complex ocean currents fields with variable isopycnals can be a considerable point of difficulty - as the energy efficient movement strategies of these gliders comes with the caveat of them being slow-moving and subject to potentially succumbing to unfavorable forces.

Glider Guidance System Development

The Glider Guidance System (GGS) is a python software toolbox designed to compile oceanographic data from various ocean physics models and return depth-averaged ocean current fields along an area of interest for a given glider mission. The methodology for this project involves compiling multiple ocean physics models into a weighted model average of density layer thickness weighted depth-averaged ocean currents. In other terms, the percent contribution of each model to the average is calculated by referencing relevant model datapoints to in-situ measurements and varying their weight in the assimilated average based on their current accuracy in the region of interest. This will help provide the best estimate of conditions and help remove failing points in the models which may appear.(2) Furthermore, the depth-averaged ocean current fields are weighted by density layer thicknesses to account for variations in how thick a current of water is over the relevant depth range of water in the data, thus making the average reflect how frequent an AUV flying through the water column will feel the respective layers current field.

Python Software Development

Configuration Management

The Glider Guidance System intakes and stores mission configurations as defined by the user for relevant parameters, including:

1. Glider/Mission name
2. Maximum AUV depth
3. Average expected AUV velocity (assuming stagnant water)
4. AUV battery capacity
5. Average expected AUV battery drain rate
6. Satisfying radius for waypoints along the mission route
7. Mission waypoints and/or start and end point of interest

GGS configurations can be integrated into the system’s runtime instances in one of three different formats:

1. ‘Static Configuration’
   1. This function is intended for debugging, providing a hardcoded configuration dictionary.
2. ‘Imported Configuration’
   1. This function allows for importing a predefined configuration from a python ‘.pkl’ external file. Importing is designed for missions where configuration parameters have been pre-determined or derived from previous missions, allowing for improved consistency and more efficient setup and run times.
3. ‘New Configuration’.
   1. For new mission configurations, this interactive function prompts the user to input details for the configuration dictionary variables.

Route Analysis

After configuration, GGS performs a meticulous route analysis through a series of interlaced functions. For each leg of the mission (waypoint to waypoint segment), it calculates the distance horizontal distance using the Haversine formula. Additionally, utilizing the glider's average velocity from the configuration, it estimates the time taken for each leg and the associated battery drain - accounting for the continuous battery consumption over time. After computations, a comprehensive overview of the entire mission, including total distance, time, and battery requirements is printed and saved for user reference. This information is crucial for mission validation and operational adjustments.

Ocean Model Data Processing

A key feature of the GGS is its ability to integrate and process real-time oceanographic data through open-access ocean model data outputs. Currently, the code only handles single-model processing (specifically only for RTOFS), so the code analysis will only evaluate its current functionality.

GGS initializes data access by first loading the RTOFS data, then setting the appropriate geographical extent based on the waypoint coordinates entered in the config (latitude and longitude). The extent of the subset is defined by the rectangular perspective which the waypoints frame out, plus a buffer in both latitude and longitude directions for viewing purposes.

After the sub-setting function narrows down the data to the area relevant to the mission's waypoints, the depth-average current function processes the data to compute the weighted current velocities at each depth by the thickness of their respective layers and averaging them into the final two-dimensional current field.

GGS Depth-Average Plot

The two-dimensional current field dataset calculated by the is displayed as a streamline plot on a cartographic map, utilizing libraries such as Matplotlib and Cartopy for geospatial plotting. Streamlines representing currents are superimposed on the mission path to visualize how the water's movement might affect the glider. Key navigational points, such as the start and end waypoints, are highlighted for clarity – however, they can be toggled on and off in calling the plot function depending on whether users have a set route in mind or if they prefer to see the current field first before plotting route points. This visual output not only serves as a navigational aid but also as a tool for communicating mission plans to stakeholders. (3)

A map of the ocean

Description automatically generated

Slocum Glider File Integration

GGS anticipates the generation of Slocum glider mission files, in order to streamline the process between route planning and mission programming. Although this section is in very early development, it stands as one of GGS's expandable framework components designed to support a variety of mission file formats.

Ongoing and Future Work

Primary GGS Focuses

Currently, the largest bottleneck in expanding the functional capacity of GGS is the availability of NOAA’s RTOFS datasets. Due to the way they are processed, the full global RTOFS dataset is only available through binary files whereas regional subsets for the United States East and West coastlines are available in netCDF format. The code to convert the binary files containing RTOFS data is not made fully available, however ongoing communication with members of NOAAs modeling department have been initiated to acquire the existing scripts which do this. Ultimately, the goal for processing RTOFS data is to pull the binary files containing the global dataset and pass it through code converting it into a netCDF format in order to allow GGS to handle the data directly.

Furthermore, expanding the handled ocean models to include Copernicus Marine Service's Global Ocean Physics Analysis and Forecast on top of RTOFS to begin using the model-weighted methodology is of high-priority interest.

***Methodology Testing and Verification Strategies***

In order to verify the validity of GGS’s output, point hand measurements will be made for ocean model dataset points to confirm that the code properly computes the thickness-weighted depth average of ocean currents and/or properly weights model assimilations (once that stage is more developed). This will begin particularly as demand for the product rapidly increases pending deployments which are set to occur around the Yucatan peninsula in a short time.

Citations

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