Water sampling from aerial drones for water quality research in coastal and inland waters

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Abstract

Water sample collection is a simple, but fundamental approach for measuring water properties that cannot currently be sensed in situ with instruments or for conducting experiments requiring water samples. Conventional approaches to water sampling typically employ research vessels which are costly, limited by sea state, and are often restricted by scheduling and other logistics. These factors can limit the ability to sample transient phenomena in inland and coastal waters. They can also restrict sampling frequency for time series measurements. We describe the use of aerial drones and newly developed sampling bottles that allow sub-surface water collection without the use of research vessels. The sampling bottles are similar in operation to conventional Niskin bottles, but with the different methods for closing the bottles. We have experimented with two closing methods. One uses a float and mechanical linkage to close bottles at fixed depths and the other uses pressure sensors to close bottles at programmed depths. Drone-based water sampling is currently employed in the Santa Barbara Coastal Long Term Ecological Research (SBC LTER) project to obtain weekly time series of water samples for pH and total alkalinity at a long-term oceanographic mooring. The water samples are also being used to calibrate pH sensors on the mooring and assess data quality. Drone sampling will be expanded to other SBC LTER moorings in the future. Aerial drones offer a new approach for sampling the coastal ocean and inland waters. Drone-based sampling is in its infancy, but we envision the development of a suite of specialized instrumentation and water collection devices that take advantage of the capabilities of aerial drones. This will allow rapid response for sampling transient events such as harmful algal blooms and toxic spills in a wide range of environmental conditions.

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1. Introduction

- Water sample collection is important for measuring water constituents that cannot be measured in situ.
- Conventional methods typically employ costly research vessels and more personnel.
- Since June 2017, water sampling by aerial drones has been employed in the Santa Barbara Coastal Long Term Ecological Research (SBC LTER) project.
- Drones collected weekly samples at an oceanographic mooring.
- Water samples are used to measure pH & total alkalinity and to calibrate a pH sensor on the mooring.
- Drone-based sampling is in its infancy, but we envision the development of a suite of specialized instruments and water collection devices for use by aerial drones.

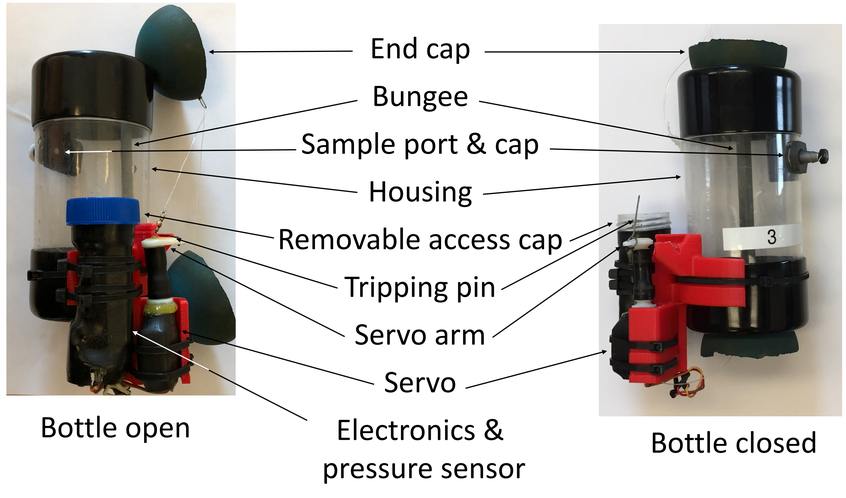
2. Technologies enabling sampling by aerial drones

New technologies facilitate drone-based water sampling:

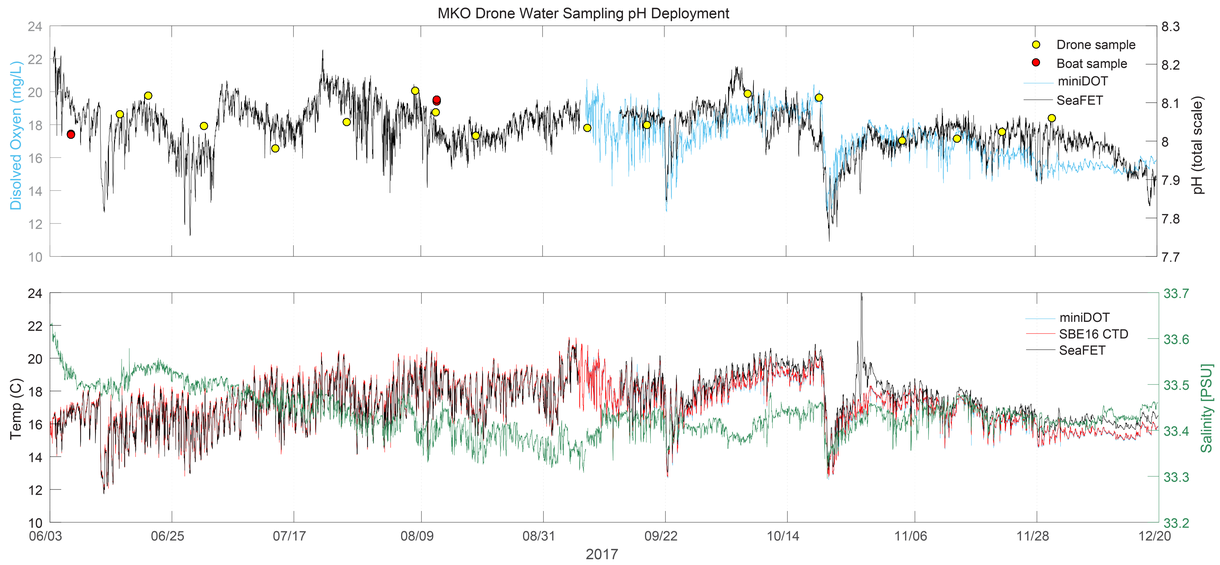
- Miniature flight control computers for aerial drones
- Open-source flight control software (e.g. Ardupilot)
- Arduino technology for electronics design for payloads
- Small, accurate GPS receivers for guidance and positioning
- Low-cost 3-D printing of lightweight components
- Lightweight batteries with increasing energy storage

3. Prototype bottle for drone-based water sampling

- Sample volume is 0.5 L.
- First prototype was tripped mechanically by surface float.
- Current prototype is tripped by sensing pressure.
- Tripping pressure is adjustable.
- Sampling depth is 5 m for pH and total alkalinity time series.

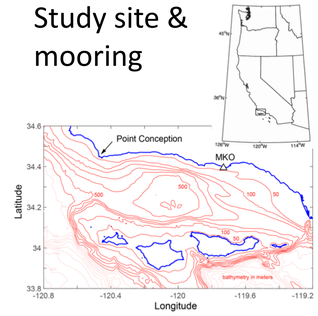


5. Drone samples for pH calibration



- Upper panel shows pH and dissolved oxygen during 2017.
- Yellow circles are drone samples. Red circles are boat samples.
- Lower panel shows temperature from CTD & Satlantic pH sensor and salinity from CTD. Data from SBC LTER mooring MKO.

Study site & mooring



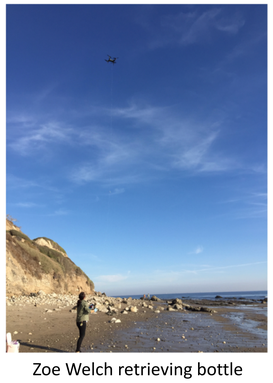
- Triangle shows mooring (MKO).
- Red lines are bathymetry.

- pH sensor calibrated from drone and boat samples using least-square procedure described by Bresnahan et al. (2014, http://dx.doi.org/10.1016/j.mio.2014.08.003) and Rivest et al. (2016, http://dx.doi.org/10.1016/j.ecoinf.2016.08.005)

4. Drone flight, water sample collection, & processing

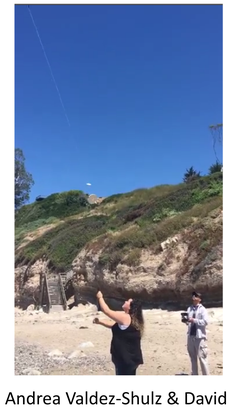

Drone taking off with bottle


Drone flying to sample location


Zoe Welch retrieving bottle


David Salazar & Zoe Welch launching drone & bottle


David Salazar preparing drone


Andrea Valdez-Shulz & David Salazar launching early sampling bottle prototype


Zoe Welch collecting water sample


Eduardo Romero designed and built sampling bottles

6. Summary and future steps

1. Drones are a feasible alternative to boats for collecting sub-surface water samples.
2. Future development efforts will focus on:
   a. larger samples volumes,
   b. deeper depth sampling,
   c. longer offshore sampling range
3. Drones can provide rapid sample collection in response to transient events such as phytoplankton blooms and runoff plumes.
4. Better guidance, flight control, & flight duration are steadily improving inexpensive, off-the-shelf drones.

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