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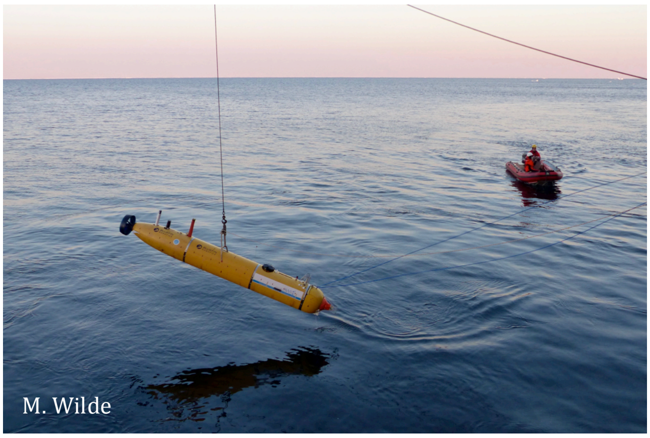

For the AUV-Team
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Measurement strategy for physical biogeochemical coupling (PBGC) at fronts

1) The Objective

Study physical and biogeochemical coupling on scales smaller than 500 m to understand the physical processes (mixing, fluxes, up- and downwelling, frontal processes) and their impact on biogeochemistry and marine life.

2) Aim of this document

This document is written to summarize the sampling strategy for studying physical biogeochemical coupling at fronts developed over the last years by the AUV team at AWI (AUV – autonomous underwater vehicle). The idea is to maintain the knowledge and to pass it on to interested people or cooperation partners. The focus is on the AUV itself. **Cooperating partners might want to directly jump to the section 6 Cooperating Infrastructure.**

3) Method

a) Find an Area of Interest

To find an area of interest, satellite data are supposed to provide a large-scale overview of the environmental conditions.
Prior to the cruise, satellite data of SST, Ice, and chlorophyll distribution in the cruise area should be monitored (e.g. ice maps from IUP Bremen). If possible, it should be organized that these maps are also available on the ship during the cruise. A person at the institute could assist in transferring useful information for dive planning. Furthermore, map plots of SST could be created and sent to the ship (via FTP or by mail).

b) Find a Front

To find a front in the area of interest, the ship´s underway thermosalinograph will be applied. Sudden changes in temperature and salinity will be used as proxies to detect a frontal system. Often it is possible to detect a front by surface features such as ice, different colours, or “foam” on the water surface. Frontal systems showing a strong biological signature will be investigated preferably. In case a possible dive site is detected, the ship will try to cross the front multiple times to determine its orientation.

c) If there is Ice

In case there is ice, the ice drift needs to be determined. Deploy tracker on the ice using drones if available. Using the zodiac is possible but, depending on the structure of the ice, it can be quite challenging. Ice conditions can change within minutes such that trackers might not be retrievable.

d) Sound Velocity Profile

Conduct a CTD (conductivity-temperature-depth) cast with the ship´s CTD to a max depth of 500m.
CTD speeds:

Downcast	0 – 100 m:	0.5 m/s
Downcast	100 – 500 m:	1.0 m/s
Upcast	500 – 100 m	1.0 m/s
Upcast	100 – 0 m:	0.5 m/s

A cast like this will take 20 minutes (in water). Process the CTD data and export the sound velocity profile in a format usable for GAPS.

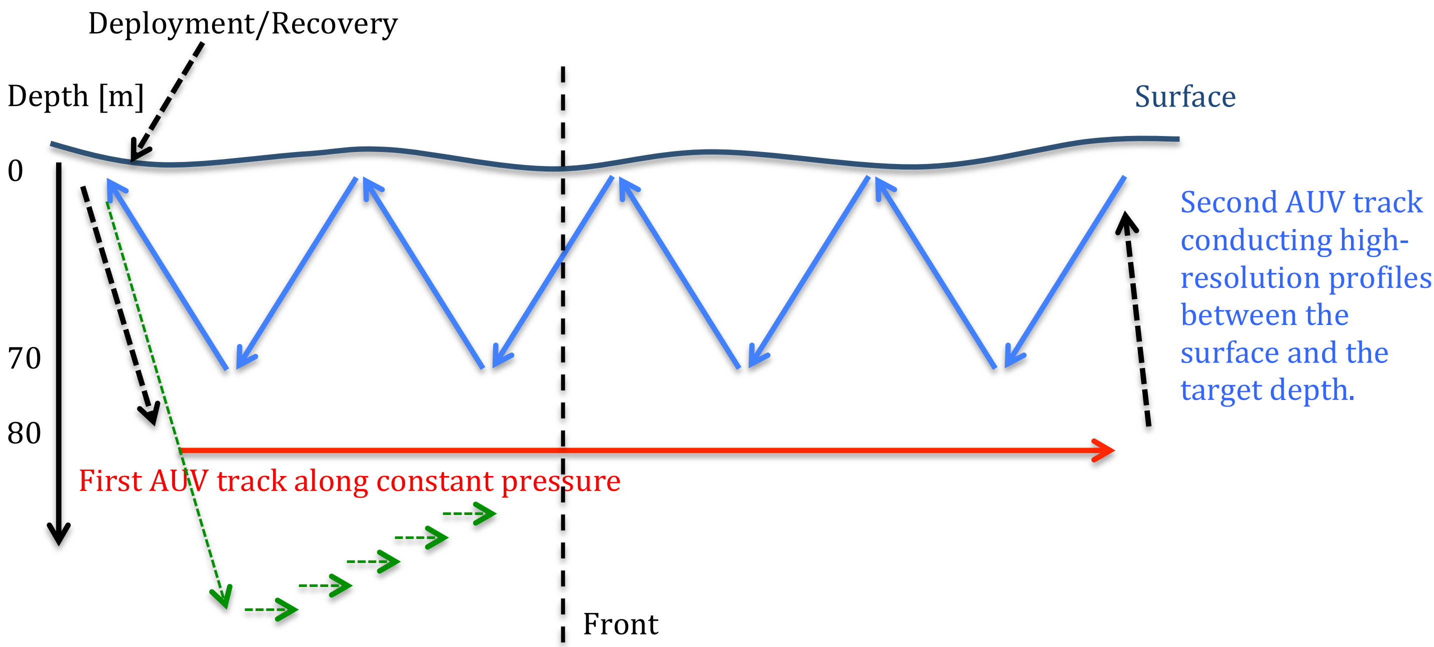
e) AUV tracking

Install tracking system for acoustic tracking of the AUV (can and should start once the ship has stopped, e.g. during the CTD Cast). Be aware that this might take a lot of time depending on the ship (1 hour on Polarstern if GAPS is used). Take into consideration that the ship will not be able to move in ice or to go faster than 6 kn with the transducer extended. Usually it takes the same time the get the system uninstalled which is particularly important if you have to search for the AUV in icy areas !

4) The AUV Dive

The AUV track should be perpendicular to the front. The dive pattern depends on the payload. If an ADCP is used without correction for pitch (as it is now), it is **important** that the AUV dive pattern consists of long horizontal segments (see figure below). If possible a dive should start with one (!) continuous (!) long transect crossing the front in a constant depth, which must not exceed the ADCP´s range. The ADCP still needs to detect the surface bin! The depth also needs to be coordinated with the triggering depth for the water sample collector. If needed the AUV can surface at the end of the long transect to receive a GPS signal and compensate for drift errors. If this is not needed it can start directly to go back.
The ADCP should be run with 1m bin length. The number of bins can be adapted.

The return transect back to the starting point should go along the same coordinates as the first transect. Now the AUV should conduct high-resolution profiles between the surface and 70 m depth. It might be needed to adapt the ADCP number of bins! In this case surfacing and uploading a new dive is needed. If so, the ship has to be in radio range (1-3 km). This needs to be taken into account when planning the additional sampling of cooperation partners!
If possible the return transect should consist of one (!) continuous (!) long transect. The surfacing spots can be used to get a GPS fix but it would be great if it were one dive (file).
If a light sensor is installed the high-resolution profiles need to contain a float every second, third or fourth profile.



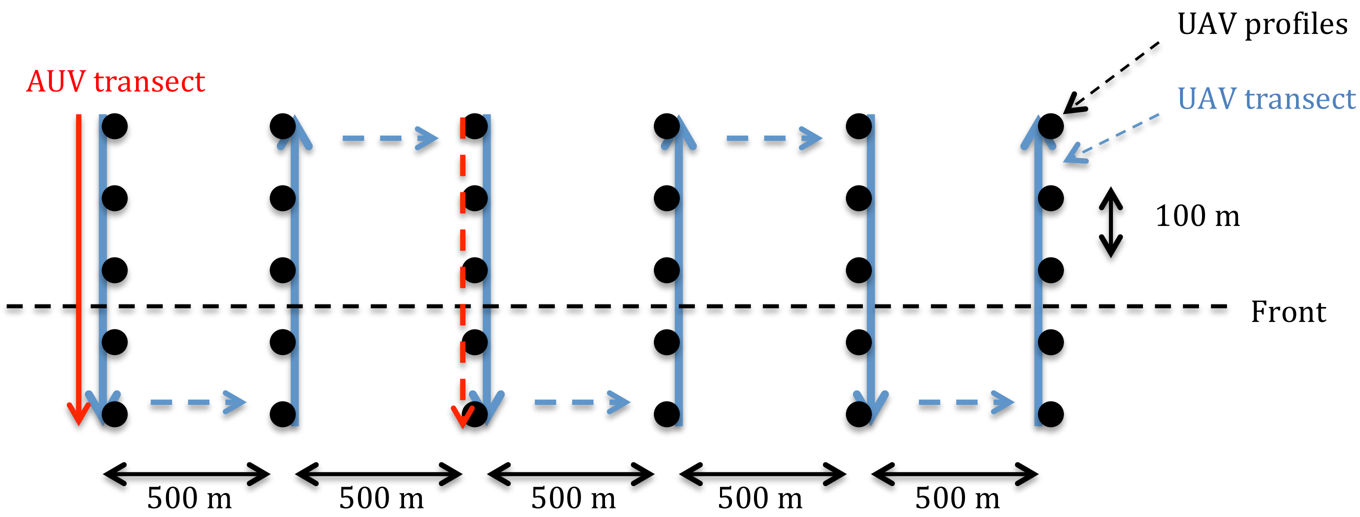
Depending on the water sample collector, it might not be possible to collect water samples on the fly (this is the case at the moment). In this case the water samples are collected at the end of the dive. It would be great if the samples could be collected along the track. This can be accomplished by sending the AUV back again perpendicular to the front and let it collect samples on the way (green in figure above). If this is to complicated to implement in the dive planning software, skip it.

5) Additional Infrastructure

a) 3D-Survey

From a physical oceanography point of view, it is **extremely important** to get an idea about the 3-dimensional structure of the front. The objective is to conduct one, but better several transects in parallel to the AUV track. Along this track, physical parameters should be measured – if possible along with basic biological parameters. This task can be accomplished using a small CTD from the zodiac or from an UAV (unmanned aerial vehicle). The distance between individual transects will be about 500 m and the tracks will be perpendicular to the front (see figure below). The consecutive spacing into one direction is **important** to avoid spatial and temporal variability to mix.

If the UAV cannot fly in such a distance to the ship, move the transects to begin with to the other side of the ship. This would mean that the location of the AUV track is reached only on the second or third UAV transect (as indicated by the dashed red error marking the AUV track). Remember to calibrate the small CTD against the ship's CTD by attaching it to the rosette before the first dive and after the last dive of the cruise. Remember the pressure rating ;)



a) Swarm of AUVs

If available, it will be extremely valuable to use other AUVs for the survey. Depending on their payload they can accomplish different additional tasks. They could for example be useful in disentangling the spatial and temporal issue, which is impossible to disentangle with only one profiling instrument. AUVs could dive on parallel transects or they could follow each other in a certain distance.

6) Cooperating infrastructure

The aim is to take as many measurements as possible in parallel to the AUV dive to characterize marine life at and around the front. Whatever samples are taken, the aim should be to take samples at both sides of the front.

b) Drifting Trap, particle camera

The drifting trap should be designed to follow the water column covered by the AUV survey, i.e. the upper 50-80m. The decision about the depth in which the traps are mounted needs to be made by the scientist operating the trap (Morten). A CTD cast might be helpful to identify useful depth. To keep track of the drifting trap, to avoid a collision and to monitor the surface currents, the drifting trap surface transponder signal could be imported into the AUV software (manually or automated). The position is interesting also already during the AUV dive because you can already see whether you will have a strong drift in the AUV position. That will help to plan all the AUV work but also additional station work. And save time!

c) CTD casts with water samples, Nets, LOKI, etc.

Species composition of phytoplankton can largely vary on the two sides of a front. Due to technical constraints, the AUV is not able to collect water samples with the dive template presented before. Thus, water samples for biological investigations need to be gathered by instruments from the ship such as the CTD-rosette water sampler and nets.
Samples should be processed to reveal the taxonomic composition of the pelagic phytoplankton.
Measurements are needed at least at both sides of the front. Better to have a cast every 2km in parallel to the AUV track. CTD casts with water samples and nets should have priority. If achievable without cutting back significantly on any other measurements other measurements along the AUV transect would be great.

d) Underway measurements

Autofilm (Katja Metfies) or similar underway measurement systems (Astrid Bracher) can be used at all times during the survey to learn as much as possible about the surface layer. Also during the very beginning of the experiment, when the front has not even been detected yet, these measurements are a very useful supplement.

e) Towed system

For the long-term perspective it will be valuable to additionally use the towed system TRIAXUS that AWI purchased in 2018.