Iceland Field Trial 2024 Report

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Hvalfjörður, Akranes

Research Objective

The primary objective of the main project is to assess Ocean Alkalinity Enhancement (OAE) processes to counteract atmospheric carbon pollution. Within this project, the 2024 Iceland Field Trial was the first research effort to guide the design of a future alkalinity release in the Hvalfjörður region.

This first experiment focused on better describing the region of interest, concentrating on possible physical constraints. It predominantly involved conducting a dual tracer release experiment. The goal was to gather data on the dispersion of surface waters and to determine air-sea gas transfer velocities within this Iceland fjord.

Narrative

The Field Trial was scheduled for 21 days, including nearly a week of mobilization, followed by a 10-day experiment and 4 days of demobilization. The team that arrived in Iceland on July 7th and started setting up the instruments on the vessel '*Bjarni Thor*' in the late afternoon consisted of Ben Hickman, Toby Koffman, Ryo Dobashi, Lennart Gerke, and David Ho. They were supported by Salome Hallfreðsdóttir from Röst and Jóhan BergÞórsson from Transition Lab. Since the laboratory on the vessel required a setup starting from scratch, one week was dedicated to assembling and securing all measurement devices and addressing electrical issues. On July 14th, the scientific crew changed, with Ben Hickman and Ryo Dobashi leaving and Ulla Heede joining the team. The remaining four-person scientific team stayed for the remainder of the experiment.

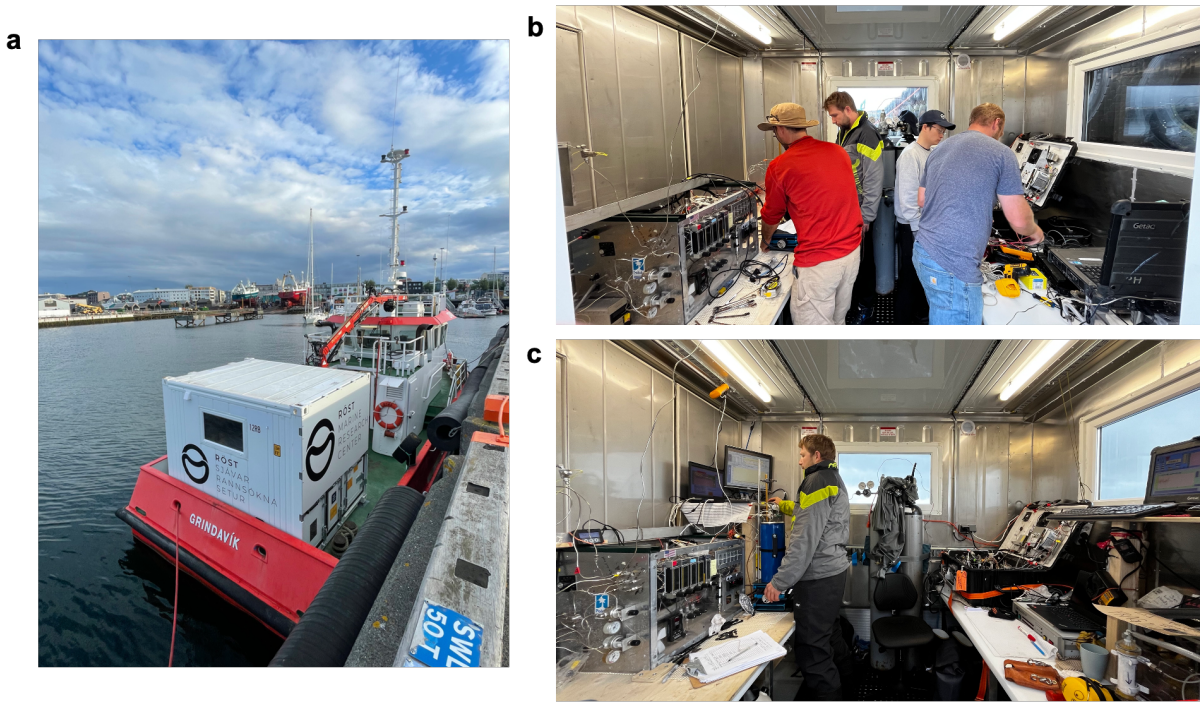

Figure 1: Images of the laboratory before, during, and after the installation. (a) The lab container on the '*Bjarni Thor*'; (b) the team setting up the lab; and (c) the final set up of the lab for the experiment.

Due to shipping delays and technical issues with some of the instruments obtained from a commercial supplier, the beginning of the tracer release experiment had to be postponed by two days. It started on July 16th with the collection of background samples and was followed by the actual tracer release the next day using a separate vessel, the 'Sæmundur Fróði' (see Figure 2). This vessel switch was necessary to prevent contamination of the measurement instruments during the release of the tracers.

Figure 2: Pictures of the tracer release on the ‘Sæmundur Fróði‘.

The sampling started in the late afternoon on the day of the release, July 17th. From July 18th, the four-person team, the captain, and his first mate went out daily on the *‘Bjarni Thor’*, starting in Akranes at 8 am and mapping Hvalfjörður until 6 pm. Underway samples were collected throughout the day, and at specific sampling stations, water samples from various depths were collected twice daily to measure SF_6 and ^3He concentrations qualitatively (see Figure 3). The sampling stations were chosen based on the highest concentrations observed in the underway data.

Due to the two-day delay at the start of the experiment, the research period was extended until July 25th, pushing demobilization back a couple of days. Nonetheless, all the equipment was packed and ready for shipment by the end of July 27th.

Figure 3: Selection of images showing the deployment of the CTD rosette and sampling for the two tracers from the Niskin bottles.

Scientific experiment

The dual tracer release experiment involves releasing a mixture of pure SF_6 and ^3He into the water and then measuring these tracers throughout the water column over the following days. The process began with a survey of the area to identify the optimal injection location, carried out on July 16th. This was combined with collecting background samples and conducting two CTD (Conductivity, Temperature, Density) sections across the Fjord at different longitudes. Once the ideal site was determined, the nontoxic tracer mixture, often used for these research purposes, was released at a defined depth (10 m) along a transect through the fjord at approximately -21.63 °W longitude. Six hours after the release, the first tracer hunt started. During this phase, SF_6 surface water concentrations were measured, searching for levels exceeding the background values and mapping the fjord. Upon detecting elevated concentrations, a CTD station was set up at this location to collect water samples from various depths

throughout the water column, permitting more detailed measurements of SF_6 and ^3He. SF_6 samples were analyzed immediately on board, while samples for ^3He were collected in copper tubes and sent to the University of Bremen for post-cruise analysis.

Figure 4: Photo taken at one of the CTD stations where the CTD rosette was being deployed from the *'Bjarni Thor'* within Hvalfjörður. *Picture by Thrainn Kolbeinsson*

The underway SF_6 data and discrete samples measured at the CTD stations provide insights into the dispersion and movement of the surface water within the fjord. This recorded data across the entire fjord over the nine-day observation period yielded information on the speed and direction of water movement. Analysis of the ratio of SF_6 to ^3He in water samples collected from various depths twice a day at CTD stations enables a determination of the gas transfer velocity. Including wind speed data of the corresponding days will further benefit the analysis, revealing the correlation between gas transfer velocity and wind speed in this location.

Preliminary results

Figure 5 shows the initial results of the underway measurements. The plot shows the distribution of SF_6 surface water concentrations 48 hours after the tracer release. The data indicate that at this point, some of the released tracers had already reached the mouth of the Fjord.

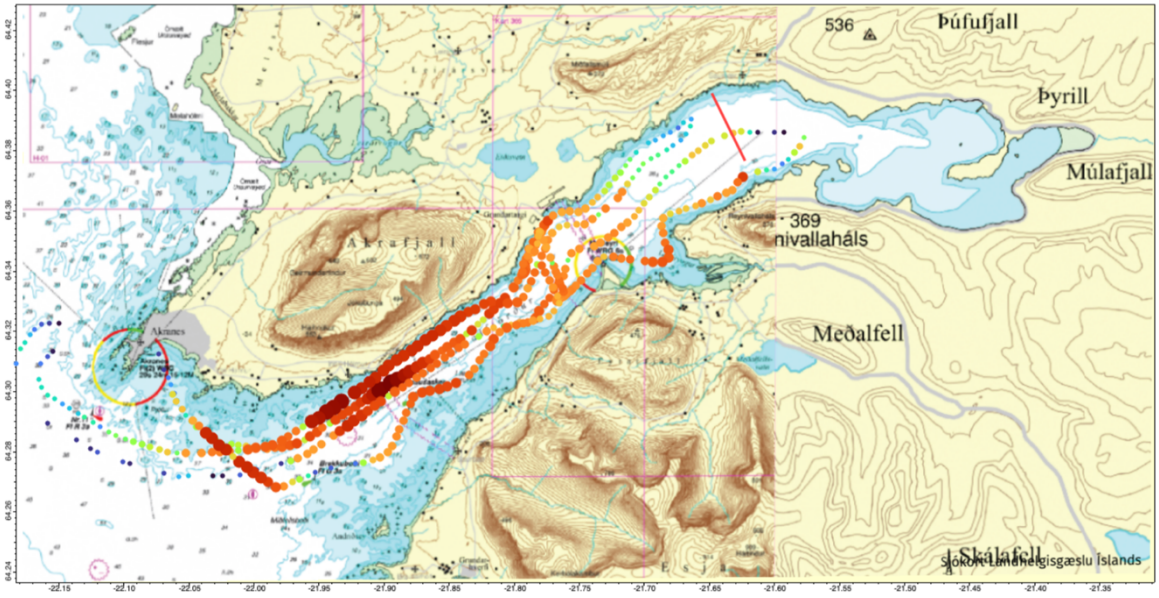

Figure 5: Distribution of surface water SF_6 concentrations throughout the fjord 48 hours after the tracer release. The red line marks the location of the tracer release, while the size and color of the dots represent the concentration of tracer detected at each location. Red indicates high concentrations, while green shows low concentrations. *Plot by David Ho*

Preliminary results of the discrete SF_6 measurements at the respective CTD stations reveal that the tracer had quickly spread throughout the entire water column, from the surface down to 35 meters, the deepest point of sampling. SF_6 concentrations measured exceeding the background values at all depths indicate a well-mixed water column. These enhanced concentrations were also measured eight days following the injection, indicating that the innocuous tracer was still present within the fjord by the end of the experiment. Figure 6 illustrates the measured concentrations on the last day of the experiment (afternoon).

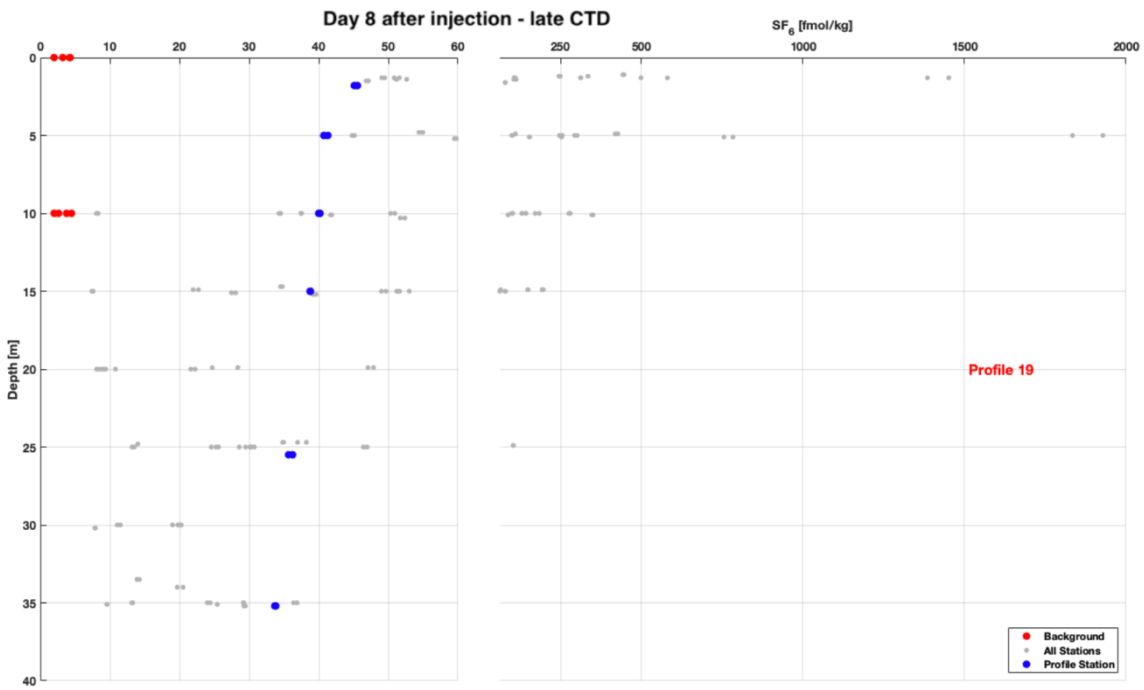

Figure 6: SF_6 concentrations measured within the water column at distinct locations. The blue dots show values measured in the afternoon of day 8 post-injection, the red dots show the background concentration, and the grey dots show data from the other days. *Plot by Lennart Gerke*

Further insights into air-sea gas exchange and the overall movement of the water in the fjord will be obtained after the ^3He samples are analyzed at the University of Bremen in the laboratory of Dr. Jürgen Sültenfuß, Department of Environmental Physics.

Future Projects

Beyond the primary research goals of gathering data on dispersion and air-sea gas exchange, this field trial also served as a test on how to conduct research on a non-specialized vessel and how to operate effectively in the Hvalfjörður region to perform a potential alkalinity release the following year (permit pending).

Several adjustments were necessary throughout the trial. For instance, using a separate vessel for the tracer injection was an unplanned but essential change. Additionally, setting up the lab required more effort than planned, including installing additional hardware and facility optimizations. The original plan to collect water samples on the boat and analyze them onshore after each research day was also

modified. Instead, the team measured the discrete SF_6 samples directly on the boat, which proved more efficient given the circumstances.

Acknowledgements and Funding

We thank the captain and his first mate for their help on board, for cooperating and enabling us to map the tracer throughout the entire fjord, and for helping out during the deployment and retrieval of the CTD-rosette. We also gratefully acknowledge the onshore help of Jóhan BergÞórsson from Transition Lab and Salome Hallfreðsdóttir from Röst.

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