

Referee #1

Here the authors present data from two deployments of pH sensors that operate at different frequencies. By deploying a pH optode alongside their LOC (lab on chip) pH sensor, they were able to demonstrate that the greater accuracy provided by the LOC pH measurement could be used to correct drift in the pH optode signal. This opened up the ability to measure pH at far greater frequency by the LOC sensor alone for longer duration using the higher frequency optode that is prone to more rapid drift. An ISFET-based pH sensor package was deployed alongside as well to provide an independent indication of optode performance and assessment of the LOC applied correction in addition to bottle samples. As part of the study, it was also determined how often the optode benefitted from the correction by the LOC sensor.

A few comments:

1. Line 74: ISFET-based pH warmup time depends on choice of reference electrode. If using the Cl- ISE, there is a longer conditioning requirement.

*Thank you for pointing that out. We see that the Deep SeapHOx V2 (used in the present study) only has an external Ag/AgCl reference electrode and not in addition to an internal (gelled electrolyte) Ag/AgCl reference electrode. This results in a longer conditioning time and as such the salinity correction to the pH becomes quite important. We have added the following text highlighted in blue to the manuscript on **page 3, lines 82-86** to clarify this:*

“The conditioning time is dependent on the reference electrode configuration e.g., the Deep SeapHOx V2 only has an external Ag/AgCl reference electrode whereas the shallow-water SeapHOx and SeaFET units utilise an external Ag/AgCl reference electrode in addition to an internal Ag/AgCl (gelled electrolyte) reference electrode. As a result, the Deep SeapHOx V2 sensor (used in the present study) requires a longer conditioning time in the sensing environment and the salinity correction to the pH data becomes quite important.”

2. Table 1 (and text above): Size of sensors is a little unusual to include without more details- why list the size of the seafet if you deployed a seaphox? Is this just the sensor or the electronics, housing, power, etc.? Sensor footprint is different from a fully autonomous package.

*The LOC and optode sensors are only pH sensors, so we wanted to compare the physical size to the most relevant ISFET-based pH only sensor (hence the SeaFET dimensions), but we have now changed this to reflect the Deep SeapHOx V2 sensor used in the present study. We have added the following text highlighted in blue to the manuscript on **page 5, lines 141-143** to clarify this:*

“The sensor dimensions reported in Table 1 are of the exterior housing to give an indication of the overall footprint that is relevant to physical integration onto vehicles/platforms, but the optode and SeapHOx were operated as fully autonomous systems whereas the LOC sensor utilised an external power supply.”

3. Line 159: I don't recall mention of pH scales used. It is important when comparing different sensors to describe which scale is being used and where/how conversions are being applied. What is the composition of the pyroscience calibration solutions?

*The pH reported is the total proton scale (pH_T). We have added the following text highlighted in blue to the manuscript on **page 6, lines 165-166** to clarify this:*

“The pH values are reported on the total proton scale (pH_T), and no signal averaging was done to any data within the present study.”

Unfortunately, the composition of the PyroScience buffer solutions is not disclosed but they do recommend using their specific pH 2 / pH 11 buffers instead of common commercial buffers that contain preservatives, and the fact some can be coloured solutions that may impact the optical calibration.

General:

4. It would be useful to discuss the decisions behind the measurement frequencies of the different sensors and the decision to change during phase 2

The SeapHOx and optode pH sensors were set to sample at a comparatively high frequency (<1 min per measurement) during phase 1. This high frequency was selected to represent use cases when high-frequency data is required in fast-changing environments and aimed to ascertain how the sensors performed in the field when sampling at this rate and to understand if the sampling frequency impacted the sensor performance. While the LOC pH sensor has a maximum sampling rate of every ~10 min, in this study it was set to sample at a much lower frequency (ca. every 1 hr) to negate the need for very frequent battery swaps.

*During phase 2 the sample frequencies were decreased to test the hypothesis that the rate of sensor drift was an effect of the number of samples measured rather than simply a function of time. We have added the following two bits of text highlighted in blue to the manuscript on **page 9, lines 259-261** and **page 10, lines 270-273** to clarify this:*

“The measurement frequency was reduced during phase 2 to examine the effect of sample frequency on the drift of the optode (e.g., via photodegradation) and to conserve battery during the colder months of the deployment.”

and

“Furthermore, the reduced measurement frequency within phase 2 does not appear to show the same rate of significant signal drifting as encountered towards the end of phase 1. This could be a result of the colder temperatures experienced in phase 2 where the temperature decreased gradually from ca. 20 °C to ca. 8 °C or an outcome of the lower measurement frequency.”

5. From a scientific standpoint, it might be useful to include known observational sites or studies, BGC activities, etc. where having increased resolution would provide new or interesting information.

*We have added the following text highlighted in blue to the manuscript on **page 2, lines 37-42** to clarify this:*

“Fast pH measurements can be useful in several settings e.g., dynamic estuarine and coastal regions or on ship underway systems which can experience rapid changes in the composition of the surface and near-surface seawater (Zheng et al., 2025; Abmann et al., 2011). Furthermore, short-term anthropogenic perturbations such as runoff, upwelling and localised CO₂ emissions can create rapid pH changes (Schaap et al., 2021; Monk et al., 2021). High-frequency pH sensors can detect these transient signals that discrete sampling would otherwise miss, which highlights the need for accurate, rapid, and autonomous seawater pH sensors.”

6. Was there any averaging used in the sensor signal? And would this improve uncertainty for any of the sensors?

We appreciate the Referee for asking this question. Signal averaging can improve sensor accuracy by reducing the noise (i.e., increase signal to noise ratio) and minimise errors, however, no averaging was done to the data presented within this study. The raw pH data were post-processed to account for the known temperature and salinity at the time of measurement but were otherwise not processed.

We have added the following text highlighted in blue to the manuscript on **page 6, lines 165-166** to clarify this:

“The pH values are reported on the total proton scale (pH_T), and no signal averaging was done to any data within the present study.”

7. Deploying multiple different sensor packages is perhaps more cumbersome than a more unified package- why not just deploy the seapHOx? Some more discussion of why choosing the optode/LOC configuration would be helpful.

The combined sensor package can provide benefits over a single sensor. In the present study the LOC and optode sensors were deployed physically attached together but operating independently of each other. Due to the small form-factor of the optode, and the use of an identical MCBH-8F SubConn connector, the logistics of deploying the two sensor systems was not overly cumbersome. Future work will look at developing an integration protocol for this combined sensor package and establish communication procedures that could allow this type of data correction to be done in-situ.

We have added the following text highlighted in blue to the manuscript on **page 18, lines 479-482** to clarify this:

“The LOC + optode sensor system provided complementary strengths of low/stable pH offsets (LOC) and rapid (optode) data collection. Furthermore, having two sensor technologies enhances data robustness, provides flexibility in expanding modular observational networks, and removes the reliance on a single commercial platform that can be vulnerable to supply/servicing issues.”

8. Cost would be useful to include

*We are hesitant to include exact cost into the discussion, but we do understand this is an important consideration for the community. These are currently all state-of-the-art oceanographic pH sensors, and cost is a relevant factor. Therefore, we have added a “cost indication” within Table 1 (**page 5, line 139**) using a scale of £-£££ so that readers can understand the relative cost of the sensors.*