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Interactive comment on "Characterizing deep-water oxygen variability and seafloor community responses using a novel autonomous lander" *by* Natalya D. Gallo et al.

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I very much like the idea of the small-sized and hand-operated lander and I fully agree with the need for such systems for the performance of more in situ long-term observations. Yet, given the actual size and weight of the lander, the expression 'Nanolander' seems a bit exaggerated. This is just a personal opinion and is by no means meant to urge the authors to change the name of their system. In this context, the last section of the MS "A global array of deep-sea landers" goes in the same direction and appears a bit superficial with an emphasis on "selling" the system. The authors might consider to rewrite this last section increasing its profoundness.

RESPONSE: We are very grateful to the reviewer for their thoughtful and thorough review of our manuscript and for their additional suggestions for improvement. We respond to each comment in bold.

We agree in principle that the small benthic lander is not actually “nano”, however, Nanolander is now a registered proper name that specifies this scientific platform, so we maintain the name in the manuscript. The term arose to distinguish it from much larger traditional benthic landers.

We appreciate the reviewer’s perspective that the final section could be further expanded to increase its profoundness. Similarly, the first reviewer suggested we add a section of concluding remarks. As such, we have revised Section 4.3 of the discussion which was titled “A global array of deep sea landers”, which is now titled Section 5: Concluding remarks. This section now reads:

“5.0 Concluding remarks Ocean deoxygenation is a global concern, with changes in oxygen conditions potentially impairing the productivity of continental shelves and margins that support important ecosystem services and fisheries. Nanolanders provide a powerful tool to examine short-term, fine-scale fluctuations in nearshore dissolved oxygen and other environmental parameters, and associated ecological responses that are rarely recorded otherwise. Oxygen variability was strongly linked to tidal processes, and contrary to expectation, oxygen variability did not decline linearly with depth. Depths of 200 and 400 m showed especially high oxygen variability which may buffer communities at these depths to deoxygenation stress by exposing them to periods of relatively high oxygen conditions across short timescales (daily and weekly). Despite experiencing high oxygen variability, seafloor communities showed limited responses to changing conditions at these short time-scales. However, our deployments did not capture any large acute changes in environmental conditions, that may elicit stronger community responses; future studies using this platform could allow for such observations.

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Nanolanders provide a cost-effective and easily deployable tool for studying local conditions throughout the world. Many of the areas where large decreases in oxygen have been observed occur in developing countries, such as along the western and eastern coast of Africa (Schmidtko et al. 2017). Large oxygen losses have also been observed in the Arctic (Schmidtko et al. 2017), where the seafloor habitat is understudied. Due to their compact design, small landers such as DOV BEEBE can provide easy access to nearshore, deep-sea ecosystems and could expand the capacity of developed and developing countries to monitor and study environmental changes along their coastlines. We found that the Nanolander performed well and reliably over the course of the deployments, and allowed us to study seafloor community responses within the context of short-term environmental forcing. For continental margins and seafloor habitats, a global array of Nanolanders, similar in scope to the Argo program, could be envisioned. These would provide coupled physical, biogeochemical, and ecological measurements, which would greatly expand our understanding of temporal and spatial heterogeneity in nearshore deep-sea ecosystems and seafloor community sensitivity to environmental change. ”

As the paper claims to introduce a novel lander-technology, I would have wished to find a brief review of similar already existing systems. The authors mention papers by Jamieson et al. but do not provide details. Please add a few lines highlighting where your system goes beyond existing systems.

RESPONSE: Thank you for highlighting this omission. We propose adding the following text within the manuscript introduction:

“Untethered instrumental seafloor platforms, sometimes called “ocean landers”, have a long and rich history (Ewing and Vine 1938, Tengberg et al. 1995). These vehicles are self-buoyant, with an expendable descent anchor that is released by surface command or on-board timer, allowing the vehicle to float back to the surface. The novel design aspects of the Nanolander include the use of plastic spheres for both instrument housing and flotation, which allow the vehicle to be smaller and lighter. Previous generation landers, such as the landers used for the DEEPSEA CHALLENGE Expedition (Gallo et al. 2015) used syntactic foam for flotation, which is more expensive and requires a metal support frame, thus increasing weight. While glass spheres have a deeper maximum operational depth (to 10 km), the use of glass-filled polyamide spheres in the Nanolander has certain advantages including for machining, threading and bonding. These plastic spheres have a maximum operational depth of 2 km, and decrease the price point compared to using glass spheres. The compact, modular, lightweight design of the Nanolander is also a novel element, as most deep-sea landers require an A-frame and winch to deploy. Additionally, new electronic systems are used in the Nanolander, which have been developed to fit within the spatial constraints of the plastic spheres. The Nanolander is configured to collect paired physical, biogeochemical, and biological data in the deep-sea over multiple days, which is a rarity except for in areas with developed ocean observatories."

Beside oxygen, other parameters were measured (temperature, pH, saturation state of aragonite/calcite) but these were hardly mentioned in the discussion section although e.g. pH in respiration physiology is very important. Please clarify why these parameters were not further included in the interpretation of the data set.

RESPONSE: We agree that temperature, pH, and saturation state of aragonite/calcite are important parameters to consider as well, and for this reason have included this data in the description of environmental variability across deployments. However, since oxygen and carbonate chemistry parameters co-vary (Alin et al. 2012), we are not able to decouple these in our interpretation of community-level differences in the dataset. Mobile, adult fishes are not as susceptible to low pH as to changes in oxygen availability (Melzner et al. 2009, Kroeker 2013), and we therefore make the assumption that respiratory demands play an important role in driving community responses. Additional deployments, including longer-term deployments and repeat deployments at the same sites, would provide the opportunity to perform more in-depth analyses into the roles of different environmental drivers in giving rise to specific community responses. Additionally, we do not think that decreasing pH with depth is responsible for the observed shift from vertebrates to invertebrates, since many of the invertebrates at these deeper depths are calcifers, which should be more sensitive to low pH conditions.

Further comments and edits: Line 24: please explain “phest”

RESPONSE: Changed to “estimated pH” instead of “pHest”. This is a calculated pH using empirical relationships derived for this region in Alin et al. (2012). Within the manuscript, pHest is defined as: “pHest is estimated pH, calculated using empirical relationships from Alin et al. (2012).”

Line 67-72 in this context eddy correlation techniques could be mentioned

RESPONSE: We have added: “Eddy correlation techniques are also used to measure non-invasive oxygen fluxes at the seafloor.”

Line 108: suggest to use only metric units of m or cm instead of ft

RESPONSE: Only metric units are now included. This section now reads, “DOV BEEBE stands 1.6 m tall and is 0.36 m wide and 0.36 m deep… Within the frame sit three plastic spheres that are 25.4 cm in diameter…. When DOV BEEBE is deployed, the vertical distance from the base of the Nanolander to the seafloor is $\sim$51 cm (Fig. 1B).”

Figure 1, suggest to include a more detailed technical drawing of the lander (i.e. better version of Fig. 1A) where the different major components are labeled with numbers which can referred to in the main text. Figure 1D is not really providing any additional information and could be omitted. Please provide in the final version of the MS the figures in sufficient resolution.

RESPONSE: We have provided an additional technical drawing of the lander as New Figure 2. This could be included as a supplement or within the manuscript, depending on the preference of the reviewer and editor. The caption that goes with the labels is as follows:

New Figure 2: The primary components of the Nanolander design that yield it's relatively small size and lightweight are: 1) Spectra Lifting bale; 2) HDPE centerplate; 3) 25.4 cm in diameter polyamide spheres stacked top, middle and bottom, 4) sphere retainer (3 ea); 5) auxiliary 17.8 cm in diameter flotation sphere; 6) oil-filled LED light, one port side, one starboard side; 7) Seabird MicroCAT-ODO in the lower payload bay; 8) central fiberglass frame; 9) stabilizing counterweight; 10) anchor slip ring; 11) expendable iron anchor (bar bell weights); 12) burnwire release and mount, one port side, one starboard side; 13) Edgetech hydrophone for acoustic command and tracking; 14) HDPE side panel, one port side, one starboard side; and 15) surface recovery flag. Not shown: drop arm on front.

We have kept Figure 1D within the manuscript figure because it showcases that the Nanolander fits exactly in a horizontal configuration within a Panga, or small boat. These types of boats are readily available all around the world and are typically used by artisanal and recreational fishermen. Thus being able to transport, deploy, and recover the Nanolander in these boats increases the potential for using this scientific platform in many regions of the world, both developed and developing.

Line 111: "glass filled" sounds a bit odd; do you mean glass-spheres housed by polyamide protective shells?

RESPONSE: The plastic spheres are an injection-molded polyamide (nylon) with 30% glass fibers for additional strength. The composite approach is similar to FRP (Fiber Reinforced Plastic), or "Fiberglass", but using nylon as the binder, not polyester epoxy. We have clarified this in the manuscript and modified it to read, "Within the frame sit three plastic spheres that are 25.4 cm in diameter; the spheres are made of injection-molded polyamide with 30% glass fibers for additional strength."

Line 122: "The power supply for the BART board is housed in the upper sphere", together with the Bart board?

RESPONSE: This is correct. A battery pack supplies the power to the BART board, and is housed in the upper sphere together with the BART board. We have clarified this to read, “The power supply for the BART board is housed in the upper sphere with the BART board.”

Line 123: what would be the maximum deployment time of DOV Beebe with the given battery systems?

RESPONSE: In this study, the main technological limitation we ran into was limited battery capacity to power the LED lights; all other elements would have allowed for longer sampling (camera battery and memory, SBE MicroCAT battery and memory). The basic Nanolander itself can stay in situ for periods of 2 years, perhaps longer. However, we were only able to provide sufficient power to the LED lights for a maximum period of 14 days at the selected sampling frequency. It is unclear why during certain deployments, we experienced inconsistent power capacity for the LED lights.

Line 131: would be nice if especially details of the camera system could better show up in the improved version of Figure 1A

RESPONSE: The camera system was designed by Ronan Gray (SubAqua Imaging Systems, San Diego, CA) and William Hagey (Pisces Design, La Jolla, CA) and uses a modified Mobius Action Camera with a time-lapse assembly. They provided a 10 page manual to accompany the camera system, which could be included as an additional supplement to the paper, if the reviewer and editor would like. We have attached the manual for your consideration, titled "The SphereCam Manual."

Line 153: please use metric units

RESPONSE: Changed to: “DOV BEEBE is positively buoyant in water, and is deployed with ∼18 kg of sacrificial iron weights.”

Line 178: I think there is no need to use the word “high-frequency” (it’s rather a matter of the perspective whether 5 min sampling rate is high-frequency or not)

RESPONSE: The word “high-frequency was removed”. The sentence now reads, “Upon recovery of the Nanolander, time-series data from the MicroCAT were analyzed to assess how environmental variability (O2, T, salinity) changes with depth.”

Line 194 please describe spiciness in a bit more detail, it’s likely not common to everybody

RESPONSE: We have further clarified this in the text, which now reads: “Spiciness, the degree to which water is warm and salty, is a state variable that is conserved along isopycnal surfaces (Flament 2002) and can be used as a tracer for PEW (Nam et al. 2015). We calculated spiciness using the “oce” R package (Kelley and Richards 2017) and examined how oxygen concentration varies with temperature and spiciness across depths and deployments. Spiciness is used to examine differences in spatial variation between watermasses, which otherwise may not be apparent using isopycnal surfaces because the effects of warm temperature and high salinity cancel each other out. “Spicier” water is warmer and saltier.”

Line 309 deconstructed time series - please explain in more detail

RESPONSE: This was further clarified in the text, which now reads: “When the time series were decomposed into their additive components (i.e. daily trend, underlying trend, and random noise), time series for all depths showed a clear diurnal and semi-diurnal signal (Supplement 1B).”

We have also added a citation for the R package used for the decomposition in the Methods section, “The oxygen time series for each deployment was also decomposed using the “stats” package (R Core Team 2019) to look at the trend, daily, and random signals that contribute to the overall data patterns.”

Figure 4: the labels for “day” and “night” are difficult to read – please enlarge

RESPONSE: We have enlarged the label sizes for day and night. The updated figure with the labels enlarged is attached below (labeled Figure 4 Updated).

Line 448: I am not sure whether the statement “At âĹij200 m, oxygen, temperature,

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Discussion paper

and pH exhibited high variability (Fig. 2), greater at times than the variability observed at 100 m." is correct for temperature – please check.

RESPONSE: Thank you for pointing this out. I have taken a close look at Table 1 and inspected the overall ranges and CVs for the different deployments. For D200-DM, variability for temperature was higher than during D100-DM-Spr, based on the overall range and CV, but lower than during D100-DM-Fall. Temperature variability for D200-LJ-2 was very similar to temperature variability for D100-DM-Spr but also lower than D100-DM-Fall, based on overall range and CV (Table 1). D200-LJ-1 has lower temperature variability than both D100-DM-Spr and D100-DM-Fall. Since temperature variability was only higher at 200 m than at 100 m in one case, I will clarify the sentence to read: "At âĹij200 m, oxygen, temperature, and pH exhibited high variability (Fig. 2), greater at times than the variability observed at 100 m for oxygen and pH."

Although the Figure 2 is quite attractive and informative, especially for the discussion section, when environmental variability is discussed additional Box plots might be helpful to elucidate the differences between the different deployments (i.e. depths).

RESPONSE: Thank you for your positive feedback on Figure 2. We have added additional violin plots to a new figure (New Figure 7), which additionally addresses question 4 raised by Reviewer 1. We provided the following description about this new figure:

To compare our high-frequency measurements to a longer-term dataset, we incorporated data from a nearby CalCOFI station to provide additional context to our results. We relied on data from CalCOFI Station 93.3 28 since it was the closest station to our deployments which sampled the full upper water column down to 500 m... We then used all available CTD casts for Station 93.3 28, which represented data from 65 CalCOFI cruises during the time-period between July 2003 and November 2019, and looked at how the overall variability in environmental conditions across this longer (∼16 year) time-period, compares to the overall variability in environmental conditions across our shorter (∼3-week deployments). These results are presented in a new fig-

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ure labeled New Figure 7. This figure shows how the mean, variance (indicated using +/- 1SD and +/- 2SD), and coefficient of variation (CV) for temperature and oxygen change across the upper 500m of the water column at Station 93.3 28 (Panels A-D). This figure also selects data from specific depths that relate to our targeted deployment depths (100, 200, 300, and 400 m), and shows how the variance distribution in temperature and oxygen across our ~3 week deployments compares to the observed variance at these depths over ~16 years of CalCOFI cruise measurements (Panels E-H). Additionally, we have looked for evidence of linear changes in temperature or oxygen at our targeted deployment depths (100, 200, 300, and 400 m) at CalCOFI Station 93.3 28 (Panels I-J) as additional context for longer-term change. We hope that this added analysis helps frame our results regarding variability over short timescales within the context of variability over interannual and multidecadal timescales.

Line 476 Turbidity can be related to local hydrodynamics caused by the energy dissipation of incipient internal tides at sloping boundaries affecting the suspension, transport and deposition of food particles. If you are interested, please see e.g. Mosch et al. (2012) Factors influencing the distribution of epibenthic megafauna across the Peruvian oxygen minimum zone. Deep-Sea Research I 68 (2012) 123–135 and references therein.

RESPONSE: Thank you for pointing us to this interesting study. Similarly, Reviewer 1 also raised the importance of internal tides breaking on the margin as a source of environmental variability that may also explain the high turbidity conditions observed during our 300 m deployment (see RC1 comment 6).

In section 4.1 of our discussion, we have added suggested references from both reviewers, "The high turbidity observed at this depth may be due to shoaling and breaking nonlinear internal waves that can form bottom nepheloid layers (McPhee-Shaw 2006, Boegman and Stastna 2019). On the Peruvian margin, energy dissipation from tidally-driven internal waves have been shown to influence the distribution of epibenthic organisms by increasing suspension, transport, and deposition of food particles (Mosch

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et al. 2012). High turbidity conditions have also been observed during two separate ROV dives at ∼340 m off Point Loma (unpublished, NDGallo), suggesting high turbidity conditions may be the norm at these depths on the upper slope in the SCB."

We thank the reviewer for their time and appreciate the improvements to the manuscript that have resulted from making these changes.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2020-75/bg-2020-75-AC3-supplement.pdf

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Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-75, 2020.

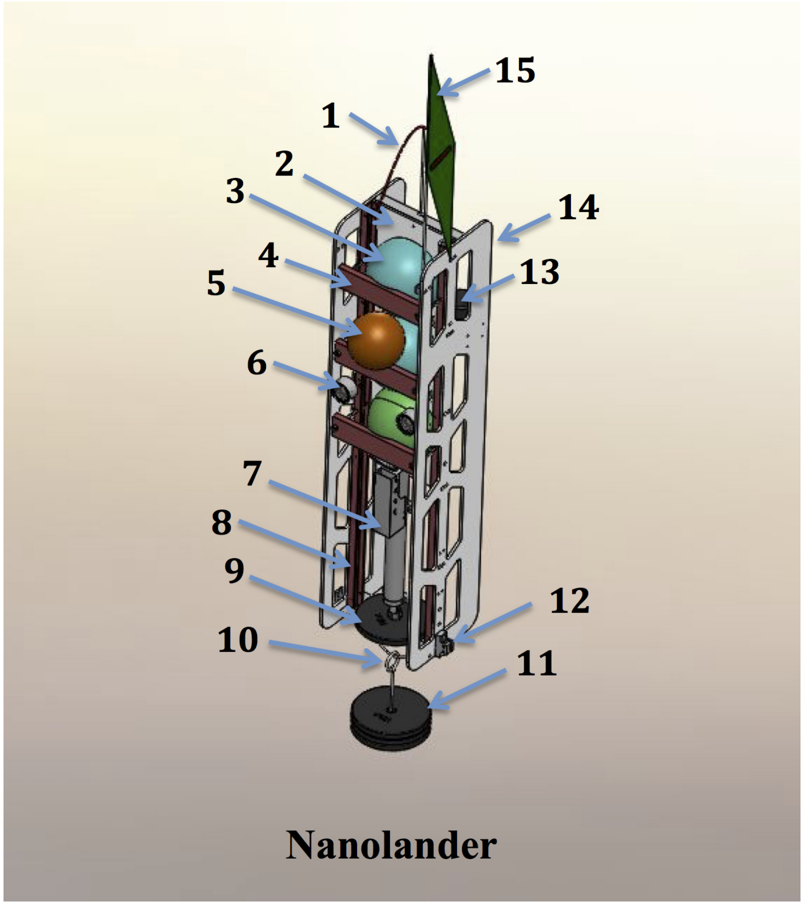

Fig. 1. New Figure 2

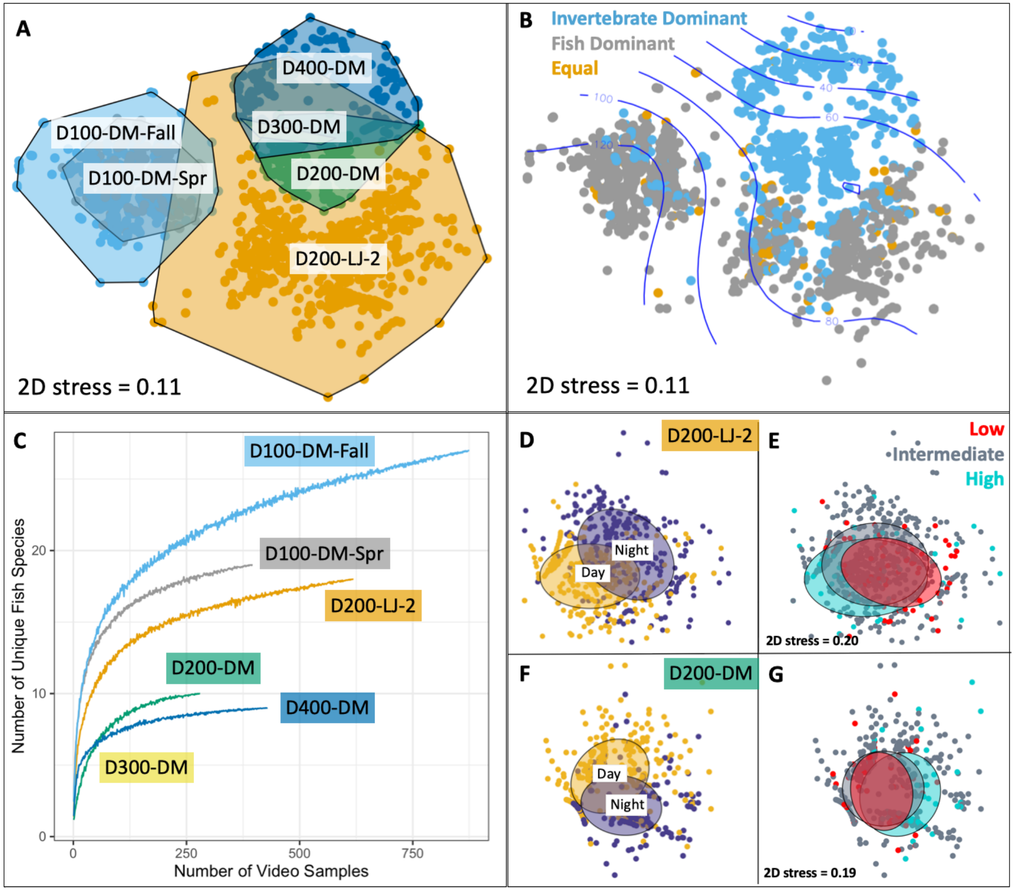

Fig. 2. Figure 4 Updated

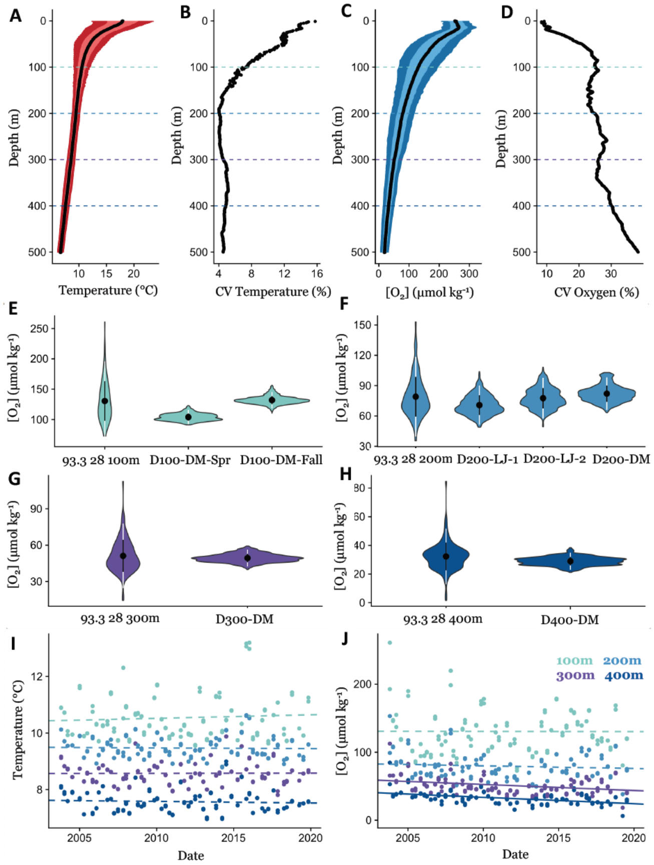

Fig. 3. New Figure 7

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