Referee 3
Interactive comment on “Drivers of the spatial phytoplankton gradient in estuarine-coastal systems: generic implications of a case study in a Dutch tidal bay” by Long Jiang et al.

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General Comments
This paper describes a coupled observational, modeling and satellite observational study of an estuarine system in the North Sea. Overall, the story and results were well conveyed and the conclusions regarding drivers of spatial and temporal variability in the estuary were supported. The main take away is that there is a Type I phytoplankton distribution and it is mainly driven by benthic grazing pressure in the landward stations. The model supports the importance of grazing pressure on the spatial distribution by numerically removing bivalves in the modeling system. Modeling estuarine primary production and chl-a distribution can be particularly challenging, and I think the author’s did a pretty good job at capturing overall NPP magnitude and some of the temporal variability, compared to 14-C NPP incubation data. The synthesis at the end is particularly useful, especially related to the discussion of how different mechanisms can lead to similar patterns of chl-a distribution, depending on the system.

Response (1): Thanks for the positive feedback and the following suggestions. We have revised the manuscript as suggested and replied to the comments point by point.

The main methodology and results that need to be improved upon, or omitted, relates to the use of the satellite observations. The author’s use one image (Fig. 10) and it doesn’t really track with the results and conclusions of the rest of the paper. In fact, the chl-a concentration is highest in the landward stations where in most observations showed lower chl-a concentration. I understand the desire to do this coupled methodological approach, but in my opinion if satellite data is to be used, it should be developed a bit more to support the observational and modeling work. There is definitely a lot of value in using these data, but acquiring more spring bloom images from MERIS data that fall within the observational window would offer a bit more support for the other results.

Response (2): Thank you for the suggestions.

The Envisat MERIS satellite data can be used to retrieve chl-a concentrations at a spatial concentration of ca 300 m (FR, full resolution data) to ca 1 km (RR, reduced resolution data). Their spatial resolutions are typically not sufficiently high for the application of the Oosterschelde, because the narrowest portions of the basin and the northern branch are around 3 km , and the Oosterschelde has intertidal flats that fall dry during low water (Fig. R1). Therefore, the land or intertidal pixels may interfere with the MERIS data in the Oosterschelde region.

van der Woerd et al. (2011) have investigated the surface chl-a in the North Sea with MERIS reduced resolution output. Their processed MERIS satellite data show that results within the Oosterschelde should be treated with caution, especially at narrow regions (Fig. R2). In contrast, the 10-m-resolution Sentinel-2 MSI data applied in our study have a spatial resolution suitable for the Oosterschelde.

In addition to the demand of a high spatial resolution, the satellite data to be used in our study also needs to be taken at high tides. One third area of the Oosterschelde is covered by intertidal flats and the water around the flats is extremely shallow (Nienhuis and Smaal, 1994). Bottom reflectance may become another source of errors at low tides (cf Arabi et al., 2019, for optically shallow water effects from MERIS full resolution images of the Wadden Sea). Availability of high tide, low cloud cover images that can show the overall spatial chl-a gradient in the Oosterschelde. are hence very limited.

Moreover, the satellite image in Fig. 11a offers, as a snapshot, valuable insight into the spatial gradient. The spatial phytoplankton pattern shown in Fig. 11a was also detected in the model output (Fig. 11b), which partly validates the model. Although the seaward increasing chl-a gradient is most common in the Oosterschelde in spring, it changes with time. That is, when discussing the spatial phytoplankton variability, we have to be aware of the temporal variability. When describing the general spatial gradient, the less general “exceptions” needs to be noticed. In the revised manuscript, we have emphasized the importance of temporal variability. The satellite image and the less frequent spatial gradient it displays (Fig. 11) fits in that standpoint. Thereby, we tend to retain Section 4.3 and Fig. 11a.

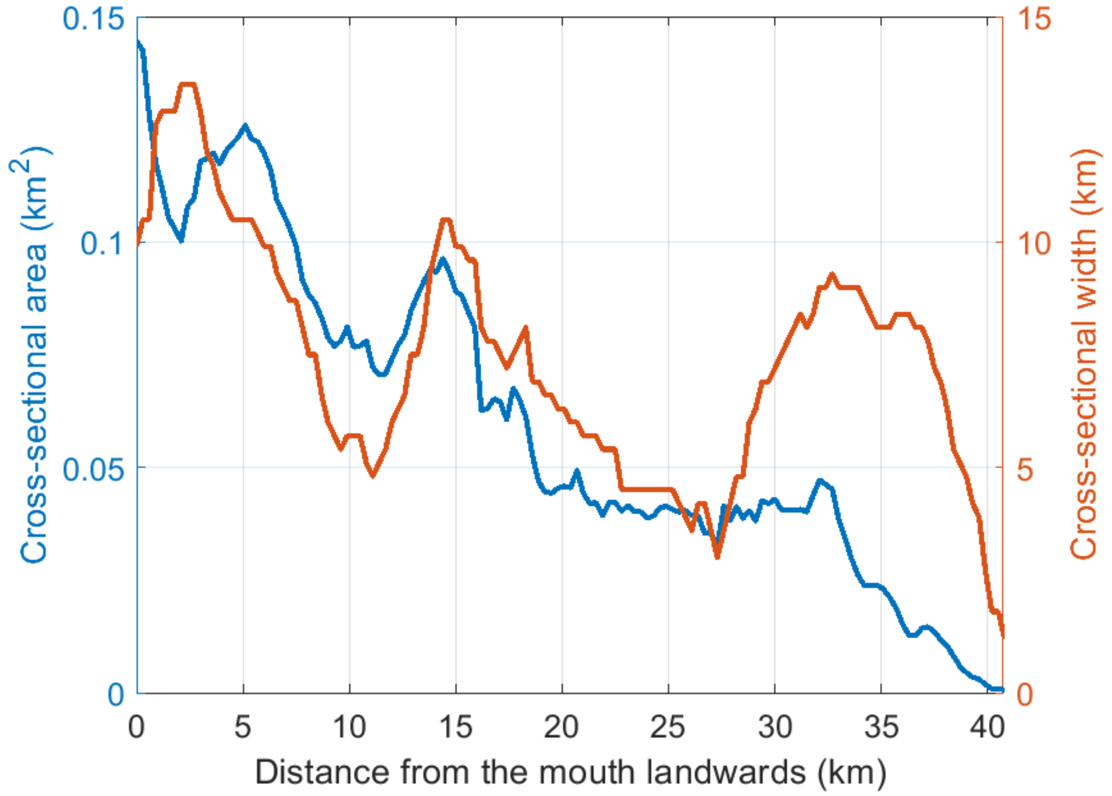


**Figure R1: The cross-sectional area and width of the Oosterschelde from the mouth to its eastern end. The northern branch (Fig. 1) is excluded from the calculation because of a different orientation of channels. This figure is Fig. 6 in Jiang et al., 2020.**

## References


Arabi, B. , Salama, M. S. , Van der Wal, D., Pitarch, J. , and Verhoef, W.: The impact of sea bottom effects on the retrieval of water constituent concentrations from MERIS and OLCI images in shallow tidal waters supported by radiative transfer modeling, Remote Sens. Environ., 237, 11596, https://doi.org/10.1016/j.rse.2019.111596, 2020.

Jiang, L., Gerkema, T., Idier, D., Slangen, A. B. A., and Soetaert, K. E.: Effects of sea-level rise on tides and sediment dynamics in a Dutch tidal bay, Ocean Sci., 16, 307–321, https://doi.org/10.5194/os-16-307-2020, 2020.

Nienhuis, P. H., and Smaal, A. C.: The Oosterschelde estuary, a case-study of a changing ecosystem: an introduction, Hydrobiologia, 282/283, 1–14, http://doi.org/10.1007/BF00024616, 1994.

van der Woerd, H. J., Blauw, A., Peperzak, L., Pasterkamp, R., and Peters, S.: Analysis of the spatial evolution of the 2003 algal bloom in the Voordelta (North Sea), J. Sea Res., 65, 195–204, ttp://doi.org/10.1016/j.seares.2010.09.007, 2011.

Specific Comments
Page 2 Line 10: This sentence with the semi-colons is oddly structured, consider revising because the information is good.

Response (3): This sentence is rephrased and split into three sentences. Please see Page 2 Lines 10–13 in the “accept-changes” version of the revised manuscript.

4-20: “Light attenuation was measured : : :” How specifically was light attenuation measured and with what instrument?

Response (4): The light intensity ($I$, μmol photons $m^{-2}$ $s^{-1}$) in underwater layers was measured in the field with Licor LI-192SB cosine-corrected light sensors connected to a Licor LI-185B quantum meter. Then the light extinction coefficient $K_d$ and light distribution in the entire water column were calculated based on the Lambert-Beer Law, $I_z = I_0 * exp(-z*K_d)$, where $I_0$ and $I_z$ are the light intensity at surface and depth $z$. We have added the information in the manuscript. Please see Page 4 Lines 25–27 in the “accept-changes” version of the revised manuscript.

4-25: “We used the measured values : : :” I don’t quite understand this sentence, consider revising.

Response (5): “the measured values” have been changed to “the measured primary production data”. Please see Page 4 Line 32 in the “accept-changes” version of the revised manuscript.

5-510: What weather forcing was used, specifically, and how was surface irradiance specified?

Response (6): We used atmospheric forcing including surface irradiance calculated from a downscaled weather model HARMONIE with a horizontal resolution of 2.5 km produced by the Royal Dutch Meteorological Institute (KNMI).

5-15: I see in the equations, detritus sinking is also calculated, but perhaps mention that here as well.

Response (7): Thanks for the suggestion. The sinking of detritus is added here. Please see Page 5 Lines 18–20 in the “accept-changes” version of the revised manuscript.

5-30: From what I can tell the bivalve biomass is constant, but perhaps clarify that here. Are the bivalves growing and dying or are they constant in time?

Response (8): Bivalves are growing and excreting nitrogen following the governing equation (22) in Table 1. However, our model does not account for the shellfish harvest mortality, occurring mostly in late summer. We have considered it as one of the limitations of the model and discussed it in the first paragraph of Discussion. Please see Page 9 Lines 10–11 in the "accept-changes" version of the revised manuscript.

6-20:25: It would be useful to show some kind of climatology of the measurements with a window or errorbars that show the inter-annual variability. See figs in Testa, J. M., Murphy, R. R., & Brady, D. C. (2018). Nutrient-and climate-induced shifts in the phenology of linked biogeochemical cycles in a temperate estuary. Frontiers in Marine. https://www.frontiersin.org/articles/10.3389/fmars.2018.00114

Response (9): Thanks for the suggestion. We have replaced Fig. 5 with a climatology graph and updated the text accordingly.

9-20: Does the decreasing depth (presumably) also cause the benthic-pelagic coupling to become stronger? Are there bivalves in the more seaward stations but because there is a greater volume of water the grazing pressure just is less, on an areal basis?

Response (10): Good point. Yes, indeed. In a recent study about the spatial variability of tides in the Oosterschelde (Jiang et al., 2020), we found that the average depth and cross-sectional area decreases landwards (Fig. R1). This geometric feature induces tidal convergence, i.e., larger tidal amplitude at the landward end. Therefore, shallower water depth and stronger tidal mixing can contribute to stronger benthic pelagic coupling and higher benthic grazing pressure in the east of the basin. We have added this point here and in Discussion. Please see Page 9 Lines 17–20 and Page 10 Lines 16–17 in the "accept-changes" version of the revised manuscript.

**Reference**

Jiang, L., Gerkema, T., Idier, D., Slangen, A. B. A., and Soetaert, K. E.: Effects of sea-level rise on tides and sediment dynamics in a Dutch tidal bay, Ocean Sci., 16, 307–321, https://doi.org/10.5194/os-16-307-2020, 2020.