Response to Reviewer #2

Always given as follows:

Referee comment: RC; Author response: AR; Changes to the manuscript

General comments

RC1: Information about the hydrodynamics of the SIS is missing, specifically the main currents should be described and compared between your model and e.g., literature references, since it is essential that the advective transport is realistically captured, which is not obvious from validating the DIN and DIP concentrations alone. Also comparing salinity to observations might help to check whether the mixing ratio between riverine and oceanic water masses is realistically captured in the model.

AR1: Thank you for your suggestions. The hydrodynamic model used in this study was the same as that in Chang et al. (2009) and Zhu et al. (2019). They have finished the general comparisons with observations (residual current pattern, monthly water temperature, and monthly salinity) for the hydrodynamic model, which confirmed that this model can generally reproduce the major hydrodynamic characteristics of the Seto Inland Sea (SIS). In addition, this model has been used to study the formation of cold bottom water and some related processes (Yu et al., 2016; Yu and Guo, 2018) as well as to calculate the water age of river water (Wang et al., 2018). Therefore, we only cited Chang et al. (2009) and Zhu et al. (2019) in the original manuscript but did not give a detailed description, which is shown as follows:

"Chang et al. (2009) compared the simulated surface residual current of this SIS hydrodynamic model with the observations. It showed that the summer and winter circulation patterns were reproduced. Significant cyclonic and anticyclonic eddies were developed near the entrance and inner part of Suo Nada, respectively, both in the simulated and observed results. In addition, the model also captured the southward current flowing to the western Bungo Channel and the southwestward current in the northern Iyo Nada, which were also evident in the observations. The model also well reproduced the observed circulation features in the Harima Nada."

"Zhu et al. (2019) compared the simulated temperature and salinity of SIS in February (winter) and July (summer) with the observations. They reported that the warm and saline waters flowed into the SIS through the Bungo Channel and Kii Channel in winter, which was consistent with the observations. For the vertical distributions in winter, both the simulated and observed results showed that the water column was well mixed throughout the whole SIS. In summer, both temperature and salinity exhibited a well-mixed pattern around the straits and a well-stratified pattern in the broad basins. Low salinity existed in Osaka Bay, forming a front structure with high salinity water in the Kii Channel."

In the revised manuscript, based on your suggestions, we will describe the main current field of SIS and compare the model results with the literature in Section 3.1. For the salinity distribution, we have obtained a long-term monthly observation dataset carried out by the prefectural fishery research centers around the SIS. We will also compare the simulated salinity results with observations in Section 3.1 of the revised manuscript.

Reference:

Chang, P.-H., Guo, X., and Takeoka, H.: A numerical study of the seasonal circulation in the Seto Inland Sea, Japan, J. Oceanogr., 65, 721–736, https://doi.org/10.1007/s10872-009-0062-4, 2009.

Wang, H., Guo, X., and Liu, Z.: The age of Yodo River water in the Seto Inland Sea, Journal of Marine Systems, 191, 24–37, https://doi.org/10.1016/j.jmarsys.2018.12.001, 2019.

Yu, X. and Guo, X.: Intensification of water temperature increase inside the bottom cold water by horizontal heat transport, Continental Shelf Research, 165, 26–36, https://doi.org/10.1016/j.csr.2018.06.006, 2018.

Yu, X., Guo, X., and Takeoka, H.: Fortnightly Variation in the Bottom Thermal Front and Associated Circulation in a Semienclosed Sea, Journal of Physical Oceanography, 46, 159–177, https://doi.org/10.1175/JPO-D-15-0071.1, 2016.

Zhu, J., Guo, X., Shi, J., and Gao, H.: Dilution characteristics of riverine input contaminants in the Seto Inland Sea, Mar. Pollut. Bull., 141, 91–103, https://doi.org/10.1016/j.marpolbul.2019.02.029, 2019.

RC2: You state that your nitrogen loads are smaller than previously reported values, as you neglect industrial and land-based sources as well as particulate forms of riverine nitrogen. It seems you also ignore atmospheric deposition? Since the main result of the paper, which is the oceanic fraction of the nutrients in the ecosystem, will be strongly dependent on the terrestrial loads you put in, please give a quantitative estimate on how large this uncertainty/error in the loads is.

AR2: Thank you for your comment.

First question: Yanagi (1997) considered the deposited total nitrogen (TN) load in rainwater when estimating the nitrogen budget in SIS. In this estimation, the net TN load of atmospheric deposition was 8% of the land input. In a coastal area of SIS during the spring of 2015, the dry deposition fluxes of particulate NH_4 and NO_3 were 2.3×10^{-7} mol m^{-2} s^{-1} and 5.5×10^{-7} mol m^{-2} s^{-1}, respectively (Nakamura et al., 2020). These atmospheric aerosols were measured on a rooftop at Kagawa College, Kagawa Prefecture, Japan. We are not sure whether they can represent the atmospheric aerosols for the whole SIS. Although there is great uncertainty, we still apply these two values to the whole SIS with an area of 23,203 km^2. The estimated dry deposition fluxes of particulate NH_4 and NO_3 for the SIS were 5.4 mol N s^{-1} and 12.7 mol N s^{-1}, respectively. They are lower than the nitrogen input from rivers, the open ocean, and sediment (64 mol N s^{-1}, 174 mol N s^{-1}, 86 mol N s^{-1}). This is the result of spring and there is no study for other seasons. Considering these uncertainties, we did not include the atmospheric deposition for the SIS.

Second question: TN load from land to the SIS was estimated by the Ministry of the Environment, Japan every five years from 1979 based on the unit load method in the catchment area of SIS (Abo and Yamamoto, 2019; Timita et al., 2016). From 1979 to 2014, the average TN load from land to the SIS was 471 mol N s^{-1}. Yanagi and Ishii (2004) indicated that the TN load estimated by the unit load method did not reproduce the inflow of TN to the coastal sea since some parts of the TN load remained on land. Yamamoto et al. (1996)

recommended the use of river flow rate to calculate the actual inflow TN load to the SIS and reported that the TN load calculated using this method was about 48% of that measured by the unit load method. Based on this value presented by Yamamoto et al. (1996), the average inflow TN load to the SIS was 226 mol N s^{-1}, which flowed into the SIS from the land through the 21 first-order rivers and about 640 other small rivers. We included 21 first rivers and 45 small rivers in our study. In addition, the compounds of TN load from land are not clear. The proportion of dissolved inorganic nitrogen (DIN) concentration in TN concentration at the first-order rivers of SIS is about 77%, which was estimated by the nutrient data from the Ministry of Land, Infrastructure, Transport and Tourism, Japan (http://www1.river.go.jp/). If we apply this value to the TN load from land, the DIN load from land is 174 mol N s^{-1}, which is 2.7 times higher than the DIN load from rivers (64 mol N s^{-1}) estimated by our study. A more extreme situation is that in addition to DIN, other compounds of TN can also be used by the phytoplankton through complex biogeochemical processes. Then, our estimation of 64 mol N s^{-1} will be 28% of the TN load from land. To consider the DIN load from land as much as possible, a new series of experiments is conducted to increase the DIN load from the rivers to 3 times its original value (64 mol N s^{-1}) to represent the DIN load from land. These experiments are being calculated and the new results will be described in the revised manuscript.

Reference:

Abo, K. and Yamamoto, T.: Oligotrophication and its measures in the Seto Inland Sea, Japan, Bulletin of Japan Fisheries Research and Education Agency, 49, 21–26, 2019.

Nakamura, T., Narita, Y., Kanazawa, K., and Uematsu, M.: Organic Nitrogen of Atmospheric Aerosols in the Coastal Area of Seto Inland Sea, Aerosol Air Qual. Res., 20, 1016–1025, https://doi.org/10.4209/aaqr.2019.12.0658, 2020.

Tomita, A., Nakura, Y., and Ishikawa, T.: New direction for environmental water management, Marine Pollution Bulletin, 102, 323–328, https://doi.org/10.1016/j.marpolbul.2015.07.068, 2016.

Yamamoto, T., Kitamura, T., and Matsuda, O.: Riverine inputs of fresh water, total nitrogen and total phosphorus into the Seto Inland Sea, Journal of the Faculty of Applied Biological Science, Hiroshima University, 35, 81–104, 1996.

Yanagi, T.: Budgets of fresh water, nitrogen and phosphorus in the Seto Inland Sea, Umi-no-Kenkyu, 6, 157–161, 1997.

Yanagi, T. and Ishii, D.: Open Ocean Originated Phosphorus and Nitrogen in the Seto Inland Sea, Japan, J Oceanogr, 60, 1001–1005, https://doi.org/10.1007/s10872-005-0008-4, 2004.

RC3: Sediment DIN flux: Your sediment model is very simplistic and maybe a bit too simplistic for your application. You assume constant DIN fluxes from the sediments in a study where you state that your goal is to understand the temporal dynamics of eutrophication. You ignore a positive feedback loop in which enhanced nutrient loads lead to more settling PON, to higher reactive TN concentrations in the surface sediment and subsequently to higher DIN release from the sediments. Please at least discuss the potential implications of this strong simplification in your discussion section. This is especially critical since sediment-water DIN fluxes are not easily observable. They tend to show substantial small-scale variation depending on e.g. the presence of bioturbating or bioirrigating macrofauna. Please give more information on what the uncertainty of the benthic flux estimates is.

AR3: Thank you for your suggestions. In our study, the DIN flux from the sediment was calculated by the surface sediment TN concentration and bottom temperature based on an empirical function (Tada et al., 2018). This empirical function is based on the measured DIN flux in the laboratory using the sediment collected in many stations in the SIS (Tada et al., 2018). The reason we used it is because it reflects the real situation in the SIS.

As we applied this formula in this study, we used the mean sediment surface TN concentration averaged from the observation data in the past 40 years, which reflected only an average state of surface TN concentration over this period and therefore ignored its long-term trend. Because the surface sediment TN concentration used in the formula is independent of the particle flux from the water column, it has not the feedback dynamic you mentioned. In fact, the only temporal variation in the DIN flux from the sediment in this study was induced by the annual variations of the bottom temperature derived from the hydrodynamic model.

Because we included the process of resuspension of particles from the sediment surface and its decomposition in the water column, we think that the short-term effects of PON settled to the sediment surface have been treated as a part of the nitrogen cycle processes in the water column. On the other hand, we also feel that it is not reasonable to treat the DIN flux from such short-term effects as a source of nutrients. In other words, our benthic nutrient flux reflects only the long-term one whose timescale is close to one year.

To make these points a little clear, we will add some sentences in the revised manuscript.

Reference:

Tada K., Nakajima M., Yamaguchi H., Asahi T., and Ichimi K.: The Nutrient Dynamics and Bottom Sediment in Coastal Water, Bull. Coast. Oceanogr., 55, 113–124, https://doi.org/10.32142/engankaiyo.55.2_113, 2018.

The revised expression is:

"It should be noted that the calculation of DIN flux released from the sediment is somewhat simple in our model. We used the annual mean TN concentration and bottom temperature based on an empirical function to calculate the sediment DIN flux. This means that we did not consider the instant effect of particulate organic nitrogen (PON) settled to the surface sediment, which can increase the reactive TN concentration in the surface sediment and subsequently higher DIN flux released from the sediment. In fact, it is difficult to treat such short-term responses of benthic DIN flux to the settled PON (Soetaert et al., 2000) as a source of nutrients because they can be a part of the nutrient cycle within the water column."

Soetaert, K., Middelburg, J. J., Herman, P. M. J., and Buis, K.: On the coupling of benthic and pelagic biogeochemical models, 29, 2000.

RC4: You consider sedimentary DIN as a "source". Actually, sediments are not a source for nutrients, but just a temporary storage or a permanent sink. The nutrients stored in the sediment are originally mostly from riverine or oceanic origin. Even if this may be somehow clear for most readers, I think it is still worth mentioning.

AR4: Thank you for your suggestions. We agree with your view. We will mention this information in Section 2.3. In addition, based on the proportion of PON flux settled on the sediment surface originating from the open ocean and rivers, we will give a quantitative estimation of the ratio of riverine and oceanic nutrients in the sediment-released nutrients in Section 4.2.

The sentences added to the revised manuscript are:

Section 2.3:

"It needs to note that the nutrients in the sediment are originally mostly from the land, or the open ocean and the sediment is a temporary storage or a permanent sink. In this study, however, we treat the sediment as the third source to track. This is because the sediment-released nutrients are gaining more attention and are particularly important in shallow waters (Radtke et al., 2019)."

Section 4.2:

"If the proportion of PON flux settled on the sediment surface produced by the oceanic and riverine nutrients were taken as the proportion of DIN flux released from the sediment, among the 86 mol N s^{-1} of DIN from the sediment, 60 mol N s^{-1} has an origin from the open ocean and 26 mol N s^{-1} from rivers."

Radtke, H., Lipka, M., Bunke, D., Morys, C., Woelfel, J., Cahill, B., Böttcher, M. E., Forster, S., Leipe, T.,

RC5: Another point maybe worth discussing is that the "oceanic" DIN can be of riverine origin, just added to the Japanese coastal waters from rivers outside the SIS. Or is it the "open" Pacific Ocean signal that is really controlling the conditions at the borders of your model domain?

AR5: Thank you for your comment. First, the DIN concentration specified at the open boundaries of our model domain was derived from the relationship between the observed water temperature and DIN concentration south of the open boundaries, which was provided in the Supplement Materials. Their strong correlation at the range of lower temperatures reflects the inherent nature of water temperature and DIN concentration of the Kuroshio subsurface water. At the range of higher temperatures, the DIN concentration is low, which reflects the nutrient-poor Kuroshio surface water.

Second, some first-order rivers are flowing into the coastal waters of Kyushu, west of Japan. In principle, these river waters can pass the Bungo Channel and Kii Channel. However, as these waters reach the areas outside the SIS, they have been largely diluted by the Kuroshio. As we know, the river discharge is at an order of several hundreds of m^3 s^{-1} while the Kuroshio has a volume transport of several tens of 10^6 m^3 s^{-1}. Furthermore, it needs more than one month for these waters to reach the areas outside the SIS and therefore most of the nutrients from the rivers have been used by the phytoplankton in the pathway.

For the above reasons, we concluded that the open boundary conditions really reflect the signals of the open ocean (Pacific Ocean). To make it clear to the readers, we will give more information in Section 2.2 of the revised manuscript.

RC6: Please give some references why it is reasonable to exclude dinitrogen fixation as a relevant N source in the SIS and neglect it in the model. (in other coastal seas it is a majour source)

AR6: Thank you for your comment. There are few studies about dinitrogen fixation for the whole SIS. In Osaka Bay, which is a severely polluted sub-region of eastern SIS, Hashimoto et al. (2016) reported a nitrogen fixation of 0.0011 mol N s^{-1} using the nitrogen fixation rate and cell abundance of unicellular diazotrophic cyanobacteria. This value was much lower than the nitrogen input of rivers into Osaka Bay (~19 mol N s^{-1}, Fig. S2). Lee et al. (1996) reported that there was no nitrogen fixation observed in Hiroshima Bay. Based on Lee et al. (1996), Yamamoto et al. (2008) assumed no nitrogen fixation in the whole SIS when estimating the nitrogen budget for the SIS. According to these studies, we think it is reasonable to exclude nitrogen fixation as a relevant N source in the SIS and neglect it in the model. In the future, we will include nitrogen fixation in the model if there are more observations available.

Reference:

Hashimoto, R., Watai, H., Miyahara, K., Sako, Y., and Yoshida, T.: Spatial and temporal variability of unicellular diazotrophic cyanobacteria in the eastern Seto Inland Sea, Fish Sci, 82, 459–471, https://doi.org/10.1007/s12562-016-0983-y, 2016.

Lee, Y. S., Seiki, T., Mukai, T., Takimoto, K., and Okada, M.: Limiting nutrients of phytoplankton community in Hiroshima Bay, Japan, Water Research, 30, 1490–1494, 1996.

Yamamoto, T., Hiraga, N., Takeshita, K., and Hashimoto, T.: An estimation of net ecosystem metabolism and net denitrification of the Seto Inland Sea, Japan, Ecological Modelling, 215, 55–68, https://doi.org/10.1016/j.ecolmodel.2008.02.034, 2008.

RC7: Section 4.2 is lacking information on how the figures presented in the article relate to previous estimates of the nitrogen budget of the SIS.

AR7: Thank you for your suggestions. We have collected some related information and will present it in this response note. We will also add this information in Section 4.2 of the revised manuscript.

Yanagi (1997) estimated the nitrogen budget in the SIS based on some assumptions. It reported that 392 mol N s^{-1} of TN was transported from the land and 31 mol N s^{-1} was deposited by rainwater. 358 mol N s^{-1} of TN was transported to the open ocean at the open boundaries, and 64 mol N s^{-1} was buried in the sediment. Our study revealed that 64 mol N s^{-1} of DIN was from rivers, among which 14 mol N s^{-1} was transported at the open boundaries and 50 mol N s^{-1} was buried in the sediment. Since we did not introduce the other types of nitrogen from rivers, our values are much lower than those reported by Yanagi (1997).

Fujiwara et al. (2006) also estimated the TN budget in the SIS and clarified the land origin and open ocean origin, showing that 330 mol N s^{-1} of TN was supplied from the land to SIS, of which 297 mol N s^{-1} was transported to the open ocean and 33 mol N s^{-1} was buried to the sediment. Fujiwara et al. (2006) also reported that the net input of TN from the open ocean was 50 mol N s^{-1}, which was buried in the sediment. In this study, the TN originating from the open ocean has a net input of 62 mol N s^{-1}, all of which was buried in the sediment.

Compared our study with the above two studies, the main difference was the amount of TN from the land. Even though they made some adjustments for the TN obtained from the original unit method calculations, the estimates given based on experience have a high degree of uncertainty and were not linked to river discharges. Fujiwara et al. (2006) also stated that TN from the land they estimated had a great deal of uncertainty. According to our answer to RC2, we believe that it is more accurate to combine the river flow and the DIN load occurring on land to give the actual load flowing into SIS in the revised manuscript.

There are also studies to estimate the DIN transport at boundaries between the SIS and the open ocean. At the south of Bungo Channel (the west open boundary of our model), Morimoto et al. (2022) reported that a net of 385 mol N s^{-1} oceanic DIN was transported from the open ocean to the SIS in July and August based on simulated water volume and DIN concentration derived from water temperature. It was 245 mol N s^{-1} in our study. The reason that our estimate is less than theirs may be caused by the outward DIN transport. We used the DIN concentration calculated by the low-trophic ecosystem model, which was larger than their DIN concentration. Fujiwara et al. (1997) reported about 168 mol N s^{-1} of DIN through Kii Channel from the open ocean in August of 1985. We estimated about 139 mol N s^{-1} of DIN was from the open ocean to the SIS through Kii Channel in August.

In revision, we will add the above information to the manuscript.

Reference:

Fujiwara, T., Uno, N., Tada, M., Nakatsuji, K., Kasai, A., and Sakamoto, W.: Inflow of nitrogen and phosphorus from the ocean into the Seto Inland Sea, Proc. Coastal Engineering (JSCE), https://doi.org/10.2208/proce1989.44.1061, 1997.

Fujiwara, T., Kobayashi, S., Kunii, M., and Uno, N.: Nitrogen and phosphorus in Seto Inland Sea: Their origin, budget and variability, Bull Coast Oceanogr, 43, 129–136, 2006.

Morimoto, A., Dong, M., Kameda, M., Shibakawa, T., Hirai, M., Takejiri, K., Guo, X., and Takeoka, H.: Enhanced Cross-Shelf Exchange Between the Pacific Ocean and the Bungo Channel, Japan Related to a Heavy Rain Event, Front. Mar. Sci., 9, 869285, https://doi.org/10.3389/fmars.2022.869285, 2022.

Yanagi, T.: Budgets of fresh water, nitrogen and phosphorus in the Seto Inland Sea, Umi-no-Kenkyu, 6, 157–161, 1997.

RC8: Section 4.3 occurs very unexpectedly. If nutrient load reduction experiments are performed, this should be mentioned in the methods section and the results section and not appear for the first time in the discussion section. Anyway, the model with its assumed constant sedimentary N fluxes seems not appropriate for nutrient load scenarios, since here the sediment feedback is essential. Your model implicitly assumes that as soon as some riverine N reaches the sediment in particulate form, its influence is gone. In reality, specifically in shallow near-coastal sediments, fresh organic matter that reaches the sediment can me remineralized quickly and (in case that this does not happen due to denitrification) become available for primary production again. So maybe leave just leave out this section (it adds a side-story to the main story line of the article) or move it to the online supplement?

AR8: Thank you for your suggestions. Yes, Section 4.3 is given a little unexpectedly. We will mention these sensitive experiments in the Methods section of the revised manuscript. The purpose of these sensitivity experiments is to examine the uncertainty of model results due to the change in the input flux of each source of nutrients. The processes you mentioned about the fresh matter that reaches the sediment and is remineralized quickly can be understood to be included in the nitrogen cycle within the water column in our model. This is because we introduce the resuspension processes in our model. If the bottom stress is over a critical value, the particles that reach the bottom will be returned to the water immediately. Then they will be remineralized quickly in the water column.

Again, this is also related to the definition of sediment source of nutrients. In our study, we do not want to treat such quickly remineralized nutrients as the sediment source. In our early calculation, we treated the quickly remineralized nutrients as the sediment source but found that the sediment source of nutrients became over 80% in most areas. Therefore, such bottom-touched particles were not allowed to be the sediment source of nutrients.

In the revision, we will add some sentences to explain the above points.

Minor comments

RC9: Line 30: "regulated" -> "influenced"? (Climate change has no "regulating" effect)

AR9: Agree. We will correct this in the revised manuscript.

RC10: Line 33: "presenting a different seasonal variation" -> "so their import has a seasonality that is different."

AR10: Agree. We will correct this in the revised manuscript.

RC11: Line 56: Abbreviation "COD" is not defined.

AR11: We will add its definition as “Chemical Oxygen Demand” in the revised manuscript.

RC12: Line 58: "concern about oligotrophication was raised for it" is unclear, please rephrase.

AR12: We will rephrase this in the revised manuscript.

The revised expression will be: “…raised concerns of oligotrophication.”.

RC13: Line 59: meaning of "As the first step" is unclear. Are you doing a multi-step approach, or do you indicate that you are the first who try to understand these changes?

AR13: We mean there are several steps to understanding the long-term change in the nutrient concentrations in the SIS. In this study, we conducted the climatological simulation to quantitatively evaluate the inventory of materials originating from the open ocean, river, and sediment. In the future study, we will conduct simulations for yearly and interannual variations to figure out the long-term variation of impacts of the open ocean, rivers, and sediment.

To avoid misunderstanding, we will modify this sentence in the revised manuscript.

The revised expression is:

"To initiate our understanding such long-term change in the nutrient concentrations in the SIS, …".

RC14: Line 91: "from a daily dataset" is too unspecific, please give a few more details.

AR14: We will give more details about the daily dataset in the revised manuscript.

The revised expression is:

"…from the daily Grid Point Value of Meso-Scale Model (GPV-MSM) (http://www.jmbsc.or.jp/jp/online/file/f-online10200.html) provided by the Japan Meteorological Agency."

RC15: Line 93: Please specify where your hydrodynamic boundary conditions come from.

AR15: We will specify them in the revised manuscript.

The revised expression is:

"The open boundary conditions including de-tided current velocity, temperature, and salinity were based on the model results of Guo et al. (2004).".

RC16: Line 112: "The spatial variation" -> "Spatial variation"

AR16: We will correct it in the revised manuscript.

RC17: Line 133: Wang 2002 actually only cites the method from Ariathurai and Krone (1976), please give the original reference.

AR17: We will correct it and add this literature in the Reference.

The revised expression is:

"…we followed the method proposed by Ariathurai and Krone (1976) …".

"Ariathurai, R. and Krone, R. B.: Mathematical modelling of sediment transport in estuaries, in: Estuarine

Processes, Elsevier, 98–106, 1976.”.

RC18: Line 172-177: Please state more clearly which fluxes you define at the boundaries. You state you define "zero concentration" but that is puzzling. At the land-sea and sediment-water boundaries you should have identical fluxes as for DIN for one of the tagged state variables and zero flux for the others. For the open boundary condition, this should be the same during times of inflow, but during times of outflow (in the upwind scheme) the DIN_??? should be exported according to the ratio DIN_???/DIN. Please clarify.

AR18: We will state more clearly the fluxes at the boundaries in the revised manuscript. Because we solve the DIN of each source, we have their value at the grid next to the open boundary. Therefore, we do not need to use the ratio of DIN_???/DIN to determine the flux for outflow, although its effect is the same as using the ratio.

The revised expression is:

“For the open boundary conditions, during the time of inflow, DIN_{ocean} flux had the same values as those used at the open boundaries of the hydrodynamic-biogeochemical model; during the time of outflow, DIN_{ocean} flux was given by the product of DIN_{ocean} and the outflow velocity. DIN_{ocean} flux was specified to zero at the land-sea interface and the water-sediment interface. DIN_{river} at the land-sea interface was identical to those used in the hydrodynamic-biogeochemical model, but it was set to zero at the water-sediment interface. At the open boundaries, during the time of inflow, DIN_{river} flux was set to zero and during the time of outflow, DIN_{river} flux was given by the product of DIN_{river} and the outflow velocity. $DIN_{sediment}$ was set to have the same flux at the sediment-water interface as that in the hydrodynamic-biogeochemical model, but it was set to have zero flux at the land-sea interface. At the open boundaries, during the time of inflow, $DIN_{sediment}$ flux was set to zero and during the time of outflow, $DIN_{sediment}$ flux was given by the product of $DIN_{sediment}$ and the outflow velocity.”

RC19: Line 186: Why do you use observations in 50 m depth as "bottom value" for areas deeper than 50 m? Please clarify.

AR19: According to the report released by the Ministry of the Environment, Japan (https://www.env.go.jp/content/900530598.pdf), it explained that the original data for those stations deeper than 50 m were sampled at 50 m in the Broad Comprehensive Water Quality Survey.

In order to avoid misunderstanding the definition of the bottom layer, we will modify the related sentences in the revised manuscript.

The revised expression is:

“At each station, the data were sampled from two layers: the upper layer, located 1 m below the sea surface, and the lower layer, positioned 1 m above the sea floor for stations shallower than 50 m. For stations deeper than 50 m, the data for the lower layer were obtained at a fixed depth of 50 m (https://www.env.go.jp/content/900530598.pdf).”.

RC20: Section 3.1: While Fig. 2 and Fig. 3 are good for showing how well the model captures the spatial signal, it is really hard to see by eye whether it also resolves the seasonal patterns. I suggest adding a few climatologies from the model compared to observations, for a few stations representative for different subareas of the model domain. This is probably sufficient in the supplement.

AR20: Thank you for your suggestions. The observation data from the Ministry of the Environment, Japan covers the whole SIS, and the sampling date in January, May, July, and October, representing winter, spring, summer, and autumn. Here, we show you the observed DIN and PHY concentrations averaged in each sub-region of SIS in the four seasons. Then we will calculate the simulated DIN and PHY concentration of monthly mean in each sub-region of SIS and the comparison with the observations will be provided in the Supplement Materials of the revised manuscript.

Table A1. Monthly mean DIN concentration (mmol m^{-3}) averaged from 1980 to 2018 in the SIS and its sub-regions. The value before the slash is for the upper layer, and that after the slash is for the lower layer.

	Jan.	May	July	Oct.
Seto Inland Sea	4.57/4.25	1.71/2.42	1.79/3.74	3.56/4.00
Bungo Channel	4.36/4.66	1.04/2.06	1.03/3.40	2.96/3.64
Iyo Nada	2.78/2.92	0.67/1.78	0.63/2.87	2.11/3.28
Suo Nada	1.02/1.00	0.58/0.80	0.68/1.56	1.33/1.69
Aki Nada	5.17/5.33	1.76/2.24	2.21/3.75	4.18/4.70
Hiroshima Bay	2.86/3.28	0.81/0.93	0.90/1.84	2.23/2.84
Hiuchi Nada	4.47/4.65	0.87/1.02	1.23/1.78	2.57/2.47
Bingo Nada	2.89/3.19	1.38/1.61	1.64/3.37	2.44/2.30
Bisan Strait	3.19/3.19	1.93/2.01	3.73/3.67	8.37/7.67
Harima Nada	4.42/4.60	1.39/4.03	1.07/5.62	3.82/5.04
Osaka Bay	11.82/7.13	5.67/3.76	4.16/5.84	5.60/5.36
Kii Channel	7.31/6.85	2.65/6.34	2.44/7.42	3.53/5.00

Table A2. Monthly mean PHY concentration (mg Chla m^{-3}) averaged from 1980 to 2018 in the SIS and its sub-regions. The value before the slash is for the upper layer, and that is after the slash for the lower layer.

	Jan.	May	July	Oct.

Seto Inland Sea	1.79/1.70	1.45/1.16	2.93/1.32	2.23/1.85
Bungo Channel	0.72/0.68	0.93/1.76	1.21/0.64	1.12/0.76
Iyo Nada	0.88/0.94	0.48/0.28	0.53/0.52	1.62/1.18
Suo Nada	1.56/1.99	1.41/1.85	1.24/1.48	1.75/2.03
Aki Nada	1.17/1.30	0.71/0.91	1.31/1.27	2.06/1.97
Hiroshima Bay	1.46/1.52	1.07/1.13	1.25/1.53	1.87/1.98
Hiuchi Nada	1.28/1.54	0.93/1.21	1.05/1.72	1.74/2.11
Bingo Nada	3.18/3.46	1.33/2.29	1.62/2.59	2.84/3.01
Bisan Strait	2.38/2.65	2.38/2.46	2.68/2.75	2.35/2.79
Harima Nada	0.86/1.33	0.86/0.57	1.29/0.50	1.23/1.33
Osaka Bay	5.56/2.68	5.53/1.03	18.73/1.32	7.19/2.78
Kii Channel	0.63/0.56	0.32/0.23	1.29/0.22	0.77/0.37

In addition, we also collected observed data reported in the literatures in several sub-regions of SIS to validate the seasonal variation of DIN and PHY. The collected data are presented below and the comparison with simulated results will also be provided in the Supplement Materials of the revised manuscript.

There are observed DIN and PHY concentrations averaged from 0 to 40 m depth in Iyo Nada and Bungo Channel in 2009 (Yoshie et al., 2011). We extracted these data from the figures of Yoshie et al. (2011) and organized them in the tables below for future reference.

Table A3. DIN concentration (mmol m^{-3}) and PHY concentration (mg Chla m^{-3}) averaged from 0 to 40 m depth in Iyo Nada (Yoshie et al., 2011).

	DIN	**PHY**
Jan.	No data	No data
Feb.	No data	No data
Mar.	No data	No data
Apr.	0.73±0.20	0.97±0.10
May	0.70±0.07	0.79±+0.12
June	1.09±0.25	1.28±0.20
July	1.40±0.36	1.22±0.29
Aug.	1.81±0.50	2.12±0.80
Sept.	1.72±0.30	2.29±0.35

Oct.	2.62±0.30	1.74±0.20
Nov.	4.11±0.40	1.32±0.21
Dec.	No data	No data

Table A4. DIN concentration (mmol m^{-3}) and PHY concentration (mg Chla m^{-3}) averaged from 0 to 40 m depth in Bungo Channel (Yoshie et al., 2011).

	DIN	**PHY**
Jan.	No data	No data
Feb.	No data	No data
Mar.	No data	No data
Apr.	0.75±0.26	0.94±0.49
May	1.23±0.30	0.51±0.20
June	1.39±0.45	1.06±0.22
July	2.72±0.43	1.08±0.35
Aug.	2.18±0.24	1.49±0.32
Sept.	2.34±0.00	1.53±0.00
Oct.	2.58±0.72	1.23±0.58
Nov.	3.27±0.00	0.90±0.00
Dec.	No data	No data

In Harima Nada, Nishikawa et al. (2010) described the seasonal variations in DIN concentration at the surface using monthly monitoring data obtained from April 1973 to December 2007. We organized these data in Table A5.

Table A5. DIN concentration (mmol m^{-3}) at the surface layer in Harima Nada (Nishikawa et al., 2010).

	DIN
Jan.	8.4±3.3
Feb.	6.1±3.1
Mar.	3.9±2.6
Apr.	4.2±2.7
May	4.1±2.5
June	3.6±2.8
July	4.1±4.0
Aug.	2.1±1.9
Sept.	2.6±2.6

Oct.	6.1±2.6
Nov.	7.5±2.8
Dec.	9.6±3.2

In Harima Nada, Kobayashi and Fujiwara. (2008) also reported the seasonal variations of surface and bottom DIN concentration. We organized these data in Table A6.

Table A6. DIN concentration (mmol m^{-3}) at the surface and bottom layers in Harima Nada (Kobayashi and Fujiwara., 2008).

	Surface DIN	Bottom DIN
Jan.	8.16	8.41
Feb.	8.34	8.20
Mar.	7.35	7.18
Apr.	2.91	4.32
May	1.94	4.11
June	1.32	5.11
July	2.71	7.32
Aug.	1.02	10.72
Sept.	1.15	11.12
Oct.	1.07	11.12
Nov.	4.65	7.15
Dec.	6.00	6.45

Reference:

Kobayashi, S. and Fujiwara, T.: Long-term variability of shelf water intrusion and its influence on hydrographic and biogeochemical properties of the Seto Inland Sea, Japan, J Oceanogr, 64, 595–603, https://doi.org/10.1007/s10872-008-0050-0, 2008.

Nishikawa, T., Hori, Y., Nagai, S., Miyahara, K., Nakamura, Y., Harada, K., Tanda, M., Manabe, T., and Tada, K.: Nutrient and Phytoplankton Dynamics in Harima-Nada, Eastern Seto Inland Sea, Japan During a 35-Year Period from 1973 to 2007, Estuaries and Coasts, 33, 417–427, https://doi.org/10.1007/s12237-009-9198-0, 2010.

Yoshie, N., Guo, X., Fujii, N., and Komorita, T.: Ecosystem and nutrient dynamics in the Seto Inland Sea, Japan, Interdisciplinary Studies on Environmental Chemistry, Modeling and Analysis of Marine Environmental Problems, 5, 39–49, 2011.

RC21: Line 234-238: "have already occupied most areas of the SIS": it would be better to calculate the ratio

(DIN_ocean+DIN_river+DIN_sediment)/DIN. If that is close to one everywhere in the model domain, you can estimate that your spin-up period for the tagging is completed.

AR21: We will add one figure to describe the ratio of (DIN_ocean+DIN_river+DIN_sediment)/DIN in the SIS from the first year to the third year of the tracking simulation in the Supplement Materials of the revised manuscript.

RC22: Line 373: "whose ratio is 1.4:1": The ratio between what? Subsequently more occurrences.

AR22: This ratio is between the horizontal export flux of biological particles (PHY+ZOO+PON) to the open ocean (187 mol N s^{-1}) and the vertical export flux of biological particles to the sediment (136 mol N s^{-1}).

187 mol N s^{-1}/ 136 mol N s^{-1}≈1.4

We will give more explanations in the revised manuscript.

The revised expression is:

"In the SIS, the horizontal export flux of biological particles (PHY+ZOO+PON) to the open ocean is 187 $mol\ s^{-1}$ (Fig. 9a) and the vertical export flux of biological particles to the sediment is 136 mol N s^{-1}, whose ratio is 187 mol N s^{-1}/136 mol N s^{-1}≈1.4:1.".

"For oceanic nutrients (Fig. 9b), the horizontal export of biological particles has a flux of 142 $mol\ s^{-1}$ while the vertical export has a value of 62 $mol\ s^{-1}$, whose ratio is 142 mol N s^{-1}/62 mol N s^{-1}≈2.3:1; for the riverine nutrients (Fig. 9c), the horizontal export has a flux of 23 $mol\ s^{-1}$ while the vertical export has a value of 27 $mol\ s^{-1}$, whose ratio is 23 mol N s^{-1}/27 mol N s^{-1}≈0.85:1; for the benthic nutrients (Fig. 9d), the horizontal export has a flux of 22 $mol\ s^{-1}$ while the vertical export has a value of 47 $mol\ s^{-1}$, whose ratio is 22 mol N s^{-1}/47 mol N s^{-1}≈0.48:1.".

RC23: Line 454: "the management can also be applied to the sediments": It is very unclear how you would "manage" sedimentary nutrient release, you cannot easily modify it. If this is a serious option please give more details, e.g. will you add substances to capture some of the escaping nutrients?

AR23: Thank you for your comment. We intend to raise awareness about the sediment release in the SIS. As you stated, the expression "the management can also be applied to the sediments" is not appropriate. We modify this sentence in the revised manuscript.

The revised expression is:

"it needed to pay more attention on the sediments".