

**Response to the editor comments on the revised manuscript BG-2022-183-AT1 “Particulate organic matter in the Lena River and its Delta: From the permafrost catchment to the Arctic Ocean.”**

Comment types: Authors’ Response: “AR”, Editor’s Comment: “EC”

Comment colors: Authors Response: “blue”, Editor’s Comment: “black”

Comment fonts: When it was possible, we highlighted changed text by the **bold font**, the text from the manuscript copied to this review was typed *cursive*

AR: Thank you for your review and editing of our manuscript, we highly appreciate your time and work. We have answered all your comments below and revised the manuscript accordingly. There will be a track change version of the manuscript, as well as a clean version including all modifications following your and the 3 anonymous reviewers’ suggestions. All the line numbers refer to this clean revised version.

EC: L.74: I would like the authors to specify the sampling frequency, rather than simply mentioning “approximately 5–6 samples per year are collected”

AR: As mentioned in the manuscript this is not our own sampling program, but the Arctic Great Rivers Observatory (Arctic GRO). Unfortunately, we could not find any further information regarding the frequency of sampling rather than to make conclusions on that based on data published by Arctic GRO. This is how we calculated how many samples were taken in each year. We may only suggest that the project aims to capture the seasonal changes, but at the same time sampling is restricted due to the difficulties in accessing the study area. Thus, the Arctic GRO group designed their sampling program such that as many samples as possible are taken in this logistically difficult region while ensuring that enough samples are obtained to describe the seasonal variability of the river. To avoid misreading we changed the sentence:

L70-71: *Within the framework of the ArcticGRO, depending on the year, between 4 and 6 samples per year were collected by the ArcticGRO consortium (Holmes et al., 2021).*

EC: L.75: Explain why samples were taken directly from the river’s main stems rather than from their deltas and estuaries. The rationale here is not clear.

AR: Again, since we are not involved in the Arctic GRO project we may only suggest the reason for sampling at Zhigansk. We suggest that this location was chosen due to managing the very

complicated logistics in Arctic regions. A gauging station is situated in Zhigansk city, which likely makes Zhigansk a suitable sampling spot for the ArcticGRO program.

EC: Overall, I would suggest that Lines 75–87 be rephrased in the logic and details. Here are few examples of suggestions, but I am sure while you consider these, you’ll understand how to rephrase it:

EC: - Remove “Thus” at L.75.

AR: Changed accordingly

EC: - Start a new sentence with “For example...”.

AR: Changed accordingly

EC: - Replace “of the” at L.79 with from the sampling site..

AR: L75: “*This long distance **from** the sampling site **to** the areas where the river enters the Arctic Ocean ....*”

EC: - Replace “and to characterize” with “by characterizing”

AR: Changed accordingly

EC: - The new addition at L. 76–77 need to be written as an independent sentence, and please add a reference after “one of the world’s biggest deltas”

AR: Changed accordingly

L74: “*...one of the world’s biggest deltas (Fedorova et al., 2015)*”

EC: L.98: rephrase as “more than 94% of which is frozen”

AR: We respectfully disagree with this suggestion because care must be taken and correct terminology must be used when studying permafrost landscapes. 1) 94 % of the Lena River drainage area is not frozen, but it is underlain by permafrost. Every summer the upper part of the soil is thawing forming the active (unfrozen) layer; 2) Extent of permafrost is a crucial parameter for the Arctic region and permafrost zone. Permafrost stores ancient organic matter (OM), which is being released at present due to climate change, resulting in higher OM and nutrient contents in Arctic rivers, modifying food web dynamics and changing the connectivity between terrestrial landscapes and nearshore ecosystems. Permafrost is a key object of this research that is why it is important to mention its extent.

Expressions like “...area/region is underlain by permafrost” are very common in permafrost research, which is used to describe geomorphology in the Arctic regions (for example Kutscher et al., 2017; Strauss et al., 2021; Biskaborn et al., 2019, etc).

Nevertheless, the typo in this sentence was found and edited:

L94: "... 94 % is assumed to be underlain **by** permafrost..."

EC: L101: remove "and includes". Instead, start with a new sentence "the region is covered by..."

AR: We have changed the sentence:

L96-98: *"Running from the south to the north of East Siberia, the Lena River receives OM from various sources within its basin such as Holocene and Pleistocene deposits (Yedoma), which are widespread across the region and cover approximately 3.5 % of the Lena watershed area (Strauss et al., 2013, 2021b)."*

EC: L106: Please use proper reference instead of a link. You could cite this link in the list of references and indicate when it was last accessed.

AR: L107: "...(*Lehner & Grill, 2013*)"

A reference added to the list of references:

*Lehner, B. and Grill, G.: Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrol. Process., 27: 2171-2186. <https://doi.org/10.1002/hyp.9740>, 2013*

EC: Also while reading your responses to reviewers, you replied that you defined the boundaries using the hydrosheds classification, and this classification is the most recent. I looked at the suggested ref. in that page and it is 2013, can you explain why you say so? [as Kutscher et al., 2017 is more recent?]

AR: Given the comments from Reviewer 3 and you, we agree that we should clarify the source and terminology of the subcatchments shown in Figure 1.

The delineations of the subcatchments within the Lena River catchment are based on the HydroSheds database (Lehner et al., 2013). For the purpose of this study, we combined the multiple subbasins following Kutscher et al. (2017) and Liu et al. (2005) to Lower Lena, Aldan, Vilyuy and Upper Lena.

We assume that the data used for the delineation of the subcatchments in Kutscher et al. (2017) is also based on the HydroSheds database, but there might be other sources for catchment areas.

We made changes in our manuscript to clarify the way of delineation of the Lena River subcatchments. In our opinion, the correct way of citing should be:

L100-102: *"Here, we define the Aldan and Vilyuy catchments, the Upper and Lower Lena River by the area of subcatchments of the Lena River using the HydroSheds database (Lehner et al.,*

2013) and follow the terminology for the subcatchments of Kutscher et al. (2017) and Liu et al. (2005).”

While there might be publications using a different terminology of the subbasins (as suggested by Anonymous Reviewer 3, including central Lena basin), we were unfortunately unable to find these. Any indication of the source for the disagreement by Reviewer 3 regarding this would have helped.

EC: L106: “was defined” instead of “was made”

AR: Changed accordingly

EC: L120: Please add a reference at the end.

AR: added: L116: “...(*Charkin et al., 2011*)”

EC: Figure 1:

- I would recommend being consistent with the entire manuscript by using Stolb, rather than Stolb i.

AR: We think that it is necessary to mark “Stolb i.” in Figure 1 on the map because it is a geographical location: an island named Stolb. Figures 2-4 do not include “i.” because they show not a geographical unit but a data category called “Stolb”.

To stay consistent we have added “..Island” for the next lines, if it was missing (where we write about a geographical location): L145, 226, 255, and 465

EC: - For the sampling station in the legend and symbols within the map, please remove the red diamond symbol at the sampling station (avoid too many unnecessary colors]. Replace the legend with this as follow (you can fill the markers with black color]:

**Sampling stations:**

- main stem
- ◇ Stolb
- Delta

AR: We would like to keep the color scheme for filling the symbols of the sampling stations, which we have added following the recommendation from the second anonymous reviewer (“RC2: Figure 1: Include the information on the sample number in the caption. Also, try to showcase three divisions of sample groups for easy understanding”). We have chosen these particular colors to build a connection with other figures throughout the entire manuscript. Data represented on every figure from our paper (except fig.5) are grouped into categories

according to the location of sampling (main stem, Stolb, Delta) and shown as symbols filled with these particular colors.

EC: L131–132: remove “as mentioned above”

AR: Changed accordingly

EC: L135–137: Please simplify this sentence. It is too wordy

AR: Changed accordingly as the sentence was split into two and changed:

L129-132: “*Since the ArcticGRO sampling site is far from where the Lena runoff enters the Arctic Ocean, biogeochemical processes taking place downstream from Zhigansk and particularly in the delta are not reflected in the ArcticGRO data. Thus, the properties of water and suspended materials sampled at Zhigansk may in fact not be entirely representative of the discharge to the ocean.*”

EC: L150: explain why the samples were frozen

AR: L143: Changed accordingly: “...and immediately frozen at -10 °C **for preservation.**”

EC: L155–156: the word group o the parenthesis is awkward, please rephrase.

AR: The sentence was changed: L147: “...*We took surface water (0-1 m) at each sampling site.*”

EC: L166: How about the river samples? I fact, I did not clearly see any report on how the river samples were analyzed, were they analyzed differently

AR: The difference in sampling between riverine and deltaic samples is described in detail in chapter 2.2.

L136-142 describe riverine sampling and L142-151 explain the sampling from the delta and in L153-154 information about sampling from previous Lena Delta expeditions is given.

During the laboratory analyses, all samples regardless their origin, were analyzed in the same way.

To avoid this misunderstanding, we changed the last sentence from the chapter 2.2:

L154-155: “*This collection of samples and further analyses were conducted in the same way as for the samples from the **riverine** and deltaic transects obtained in 2019.*”

EC: L177: Typo for HCl

AR: Changed accordingly

L178: Please add ref. for the tin boats along with dimensions

AR: L199: “*Then they were dried again for 24 hours at 40 °C and packed/rolled into small tin boats (6x6x12 mm) (Mollenhauer et al., 2021).*”

EC: L178-9: How do you know? I think that a description of this step is skipped here

AR: L170-171: “*For filters with TSM concentrations above 20 mg/L, it was expected that C contents on the filter exceeded 100 µg. For those samples, only a subsample of the filter was used.*” ”

EC: L182: shouldn't it be reported vs. VPDB?

AR: No, we used Pee Dee Belemnite standard (PDB), but not Vienna PDB standard (VPDB).

EC: L184: please add the values for these refs.

AR: L176: “*National Institute of Standards & Technology, RM 8573, USGS40) with known isotopic composition ( $-26.39 \pm 0.09$  ‰).*”

EC: L185: and the concentrations were .....

AR: Changed accordingly

EC: L194: Blank sample was determined...

AR: Changed accordingly

EC: Also in this paragraph, was pMC—percent modern carbon— included in your analyses? Wouldn't adding it strengthen your data interpretation

AR: We report our radiocarbon data in the unit of  $\Delta^{14}\text{C}$  rather than in related (but uncorrected) units like Fm or pMC. This is common practice and the correct way of referring to data from samples with a known sample collection year. It allows correction for the year of sampling so that data remain directly comparable. We refer to published studies of similar parameters like, e.g., McClelland et al., 2016 in *Global Biogeochemical Samples*.

Nonetheless, the radiocarbon results were of course first expressed in the unit of fraction modern carbon (F14C or Fm).

EC: L196: add a ref after “for determining OM age”

AR: added: L188: “*... (Stuiver & Polach, 1977)*”

EC: L197: “D14C-depleted” is not grammatically correct. A ratio cannot be depleted

AR: Correct, thanks for noting. For L189 “ $\Delta$ ” was deleted.  $\Delta$  and the  $\delta$  were also deleted for the same reason in L376, 382, L387: “*...Regardless,  $^{13}\text{C}$ -depleted values in POC.*”, L484.

EC: L215: rewrite as Figures 2–5, also Table with T

AR: Changed accordingly

EC: L223: These are not described in the methods, nor the tools that were used to measure these.

Otherwise, please rephrase as “Previous measurements of .... [then add ref]”

AR: L212-214: “*Previous measurements using a Conductivity, Temperature and Depth (CTD) probe during the sampling campaign showed no temperature or conductivity stratification of the water profile (Fuchs et al., 2022).*”

EC: L227: remove “In contrast to our surface water samples” and add “instead” after “samples are” For the newly added text in there, I suggest removing it and keep it for discussion

AR: The entire paragraph was removed from the Result chapter. The information from this paragraph was added to the Discussion chapter 4.2.2, L463-466 as suggested.

EC: L233: Since you report this here, this definitely requires you to describe how river water samples were sampled and analyzed in the methods. Please make sure to include that.

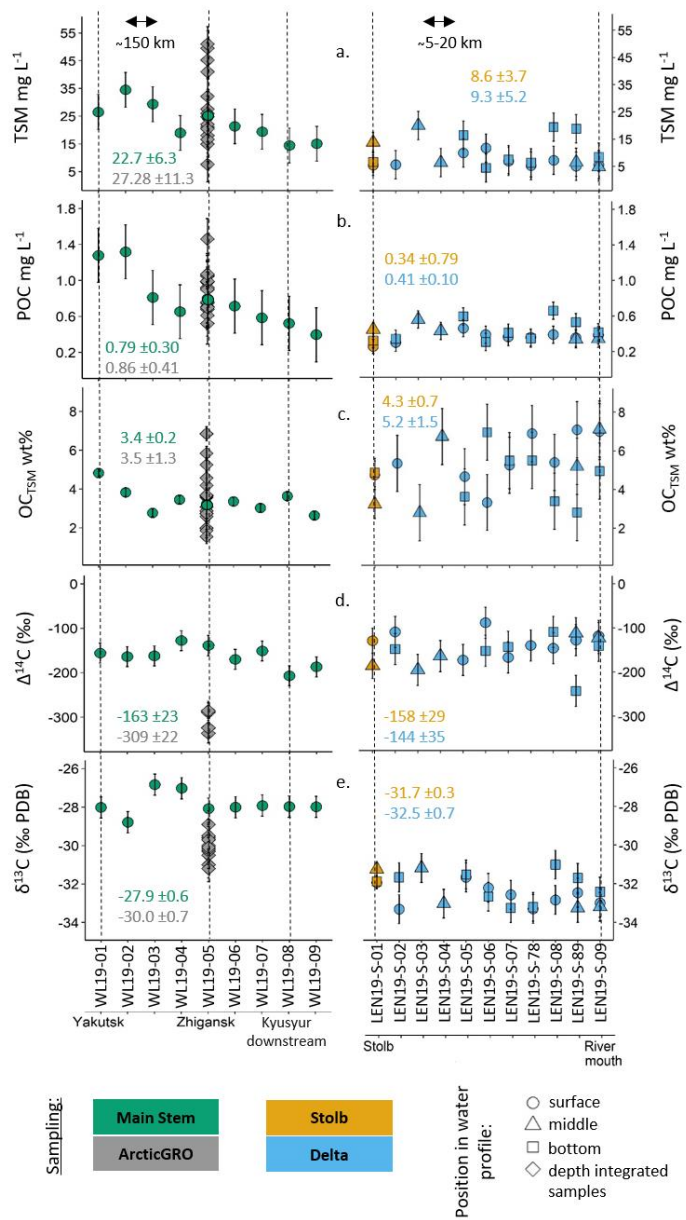
AR: Clarification was added to the Methods as it was suggested above.

EC: L247-8: I agree with this, but you could also emphasize that ArcticGRO database has greater TSM range than yours [if I interpret you figure properly]

AR: L233-234: “*TSM reported in the ArcticGRO dataset varied **within a greater range than our main stem samples result** (7.6 and 51.0 mg L<sup>-1</sup>) **nevertheless**, the average TSM (27.8 ±11.3 mg L<sup>-1</sup>) was similar to that of our main stem sample result.*”

EC: Figure 2: It is better to put the ArcticGRO datapoints behind your datapoints so it is easy to assess where your samples plot vs. ArcticGRO points.

AR: Changed accordingly



EC: L255: again, reporting river data without method description makes reader doubt about the research, please ensure to add methods pertaining to rivers.

AR: Clarification was added to the Methods as it was suggested above.

EC: L259: WL19-02 with a value of ..... respectively [also remove the extra “.” before the coma

AR: Changed accordingly

EC: L261: Space forgotten before “The”, also please rephrase as “ The samples with high TSM...”



AR: Changed accordingly

EC: L264: why reporting two highest values? Are you referring to a reference threshold?

AR: We have changed the sentence: L248: “*The average POC concentration from ArcticGRO is  $0.86 \pm 0.41$  mg L<sup>-1</sup>, within the range of 0.52 -1.46 mg L<sup>-1</sup>.*”

EC: L270: I believe one of the reviewers commented on this “disembogue”. I double checked and it is not a noun. Please use proper noun, e.g., outlet? discharge?]

AR: Edited: L253-254: “*...toward the river mouth (up to 7.1 wt% for LEN19-S-09, sampled at 5 m depth).*”

EC: L280: a value translated to 2236....

AR: changed:

L263-264: “*...Radiocarbon levels of POC varied within a wide range between -243 and -88 ‰ (between 2236 and 740  $\Delta^{14}C$  years mean age, respectively)*”

EC: L284: Font looks a bit different

AR: Changed accordingly

EC: L289: rephrase as “values than what we found”, then remove “for the ArcticGRO dataset”

AR: Changed accordingly

EC: L291–2: remove this last sentence, it is redundant

AR: Changed accordingly

EC: L294: Rephrase as “a strong difference was note don the d13C of POC. In the Main Stem, d13C values were....”

AR: Changed accordingly

EC: L298: The d13C values of POC.....

AR: Changed accordingly

EC: L305: The TSM and POC

AR: Changed accordingly

EC: L317-8: Please indicate ref.

AR: The reference (Shiklomanov et al., 2021b) was added

EC: L320: I think “assessed” or “evaluated”? is a better word choice than “analysed”

AR: changed: L300: “*We assessed all ArcticGRO data on TSM and POC for the Lena River to demonstrate that...*”

EC: While I look at Figure 3, the age estimation provided earlier in the manuscript is confusing as there is no more discussion about age in the remaining part of the paper, or I may miss an important information

AR: We provided the age estimation aiming to clarify what we mean when we use such words as “old”, “older/younger OM” describing our results within the text. We added this clarification in order to reply to the comment of Anonymous Reviewer 1. The radiocarbon data results were reported as  $\Delta^{14}\text{C}$  values in ‰, as it described in the Methodology part of the manuscript.

EC: L.512: “-288 to -122 per mil” if this is so, and while referring to your age estimation above, why not referring to age here?

AR: We have chosen to report radiocarbon results as  $\Delta^{14}\text{C}$  values in ‰, as it is the correct unit allowing comparison between data sets and isotope mass balance calculations. To stay consistent we would prefer not to report these particular parts of our results as age.

EC: L525: There was a part similar to this that I suggested to remove earlier, so I suggest keeping this and removing that.

AR: we have removed the paragraph above and changed the text LL463-466 as:

*“Another explanation for the difference in  $\Delta^{14}\text{C}$  of POC between ArcticGRO and our riverine transect may be the fact that ArcticGRO samples are depth-integrated, since potentially river water masses may be stratified (e.g. Mackenzie: Hilton et al., 2015). We did not collect samples from different water depths along the river transect from Yakutsk to Stolb but instead were only able to sample surface waters, and from discrete water depths for the samples from the Lena Delta.”*

EC: L529: Please avoid as much as possible “etc.” when you write scientific paper. Do not let your readers guess. That’s a rule of thumb

AR: Changed accordingly (“etc.” was deleted)

EC: Figure 4: My question here may be very stupid, but I ask anyway. Do you think that converting ‰ values for the  $\Delta^{14}\text{C}$  is really age appropriate? What is the proportion contribution between Holocene soils and modern OC?

AR: All the elements and data on Figure 4 were reported as  $\Delta^{14}\text{C}$ ,  $\delta^{13}\text{C}$  values in ‰, without conversion into age (Endmember values (red crosses) were also given as  $\Delta^{14}\text{C}$ ,  $\delta^{13}\text{C}$  values in ‰ see Table 1). Theoretically, if our manuscript had a different aim it would be possible to convert  $\Delta^{14}\text{C}$  values into age as it is shown by Stuiver & Polach, 1977.

To answer the second question we would like to refer to Table 2 from our manuscript, where relative OM contribution to POC is represented and/or Figure 5, where this contribution was converted into absolute values of POC concentration ( $\text{mg L}^{-1}$ ).

EC: Endmember: This technical term is bothering me. Can you please define what do you really mean by endmembers? In mineralogy, for example, we use endmember as Ca-rich mineral [e.g., anorthite] and Na-rich mineral [e.g., albite], i.e., with a clear geochemical composition, and with a possible predictable mineral with varying Ca and Na composition.

AR: An application of an endmember mixing model for determination of OM sources is a very common method, used and described in multiple publications cited in our manuscript (Mann et al., 2015; Vonk et al., 2010; Wild et al., 2019; Winterfeld et al., 2015).

We provide an explanation how we use the term “endmember” in L206-207: “*Endmember modelling analysis was performed to derive quantitative estimates of the relative input of a potential C source endmember into the POC pool of every water sample and described in detail in 4.2.3.*”. Thus, an endmember is a potential C source of POC. In chapter 4.2.3 we discussed how we estimated their isotopic compositions.

EC: L544. “less depleted in  $\delta^{13}\text{C}$ ”—this is an incorrect expression, see similar comment above

AR: Discussed above and changed accordingly

EC: L548: Please list these first so it is easy to follow.

AR: We have moved this sentence three lines down: L491-492: “*To illustrate possible sources of OM, we used a dual-carbon-isotope ( $\Delta^{14}\text{C}$ ,  $\delta^{13}\text{C}$ ) three-endmember mixing model. Endmembers for the OM sources in the Lena main stem and its Delta were defined as phytoplankton (I), Holocene soils (II), and Pleistocene deposits (III)...*”

EC: L571: this is the reason why I asked earlier if you have pMC data

AR: Discussed above

EC: L581: I don’t think that “endmember” is the proper vocabulary here. May be “category”?

AR: We changed the title of the Table 1: “*Possible sources of C used for the endmember modelling and their isotopic composition (after Winterfeld et al., 2015, Wild et al., 2019, and Galimov et al., 2006)*”

EC: L603: replace “;” with “.” then start with new sentence “This..”

AR: Changed accordingly

Reference used:

- Biskaborn, B. K., Smith, S. L., Noetzli, J., Matthes, H., Vieira, G., Streletskiy, D. A., Schoeneich, P., Romanovsky, V. E., Lewkow, A. G., Abramov, A., Allard, M., Boike, J., Cable, W. L., Christiansen, H. H., Delaloye, R., Diekmann, B., Drozdov, D., Etzelmüller, B., Grosse, G., Guglielmin, M., Thomas Ingeman-Nielsen, T., Ketil Isaksen, K., Ishikawa, M., Johansson, M., Johannsson, H., Joo, A., Kaverin, D., Kholodov, A., Konstantinov, P., Kröger, T., Lambiel, C., Lanckman, J.-P., Luo, D., Malkova, G., Meiklejohn, I., Moskalenko, N., Oliva, M., Phillips, M., Ramos, M., Sannel, A. B. K., Sergeev, D., Seybold, C., Skryabin, P., Vasiliev, A., Wu, Q., Yoshikawa, K., Zheleznyak, M., and Lantuit, H.: Permafrost is warming at a global scale, *Nat. Commun.*, 95 10, 264, <https://doi.org/10.1038/s41467-018-08240-4>, 2019
- Mann, P. J., Eglinton, T. I., McIntyre, C. P., Zimov, N., Davydova, A., Vonk, J. E., Holmes, R. M., and Spencer, R. G. M.: Utilization of old permafrost carbon in headwaters of Arctic fluvial networks, *Nat. Commun.*, 6, 7856, <https://doi:10.1038/ncomms8856>, 2015
- Strauss, J., Laboor, S., Schirrmeister, L., Fedorov, A. N., Fortier, D., Froese, D., Fuchs, M., Günther, F., Grigoriev, M., Harden, J., Hugelius, G., Jongejans, L. L., Kanevskiy, M., Kholodov, A., Kunitsky, V., Kraev, G., Lozhkin, A., Rivkina, E., Shur, Y., Siegert, C., Spektor, V., Streletskaia, I., Ulrich, M., Vartanyan, S., Veremeeva, A., Anthony, K., W., Wetterich, S., Zimov, N., and Grosse, G.: Circum-Arctic Map of the Yedoma Permafrost Domain. *Front. Earth Sci.* 9:758360, <https://doi:10.3389/feart.2021.758360>, 2021
- Vonk, J. E., Sánchez-García, L., Semiletov, I., Dudarev, O., Eglinton, T., Andersson, A., and Gustafsson, Ö.: Molecular and radiocarbon constraints on sources and degradation of terrestrial organic carbon along the Kolyma paleoriver transect, East Siberian Sea, *Biogeosciences*, 7, 3153–3166, <https://doi.org/10.5194/bg-7-3153-2010>, 2010
- Wild, B., Andersson, A., Bröder, L., Vonk, J., Hugelius, G., and McClelland, J. W.: Rivers across the Siberian Arctic unearth the patterns of carbon release from thawing permafrost. *Proc. Natl. Acad. Sci. U.S.A.* 116, 10280–10285, <https://doi.org/10.1073/pnas.1811797116>, 2019
- Winterfeld, M., Laepple, T., and Mollenhauer, G.: Characterization of particulate organic matter in the Lena River delta and adjacent nearshore zone, NE Siberia – Part I: Radiocarbon inventories, *Biogeosciences*, 12, 3769–3788, <https://doi.org/10.5194/bg-12-3769-2015>, 2015