

1 Characterization of particulate organic matter in the Lena 2 River Delta and adjacent nearshore zone, NE Siberia. Part I: 3 Radiocarbon inventories

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13 14 **Abstract**

15 Particulate organic matter (POM) derived from permafrost soils and transported by the Lena
16 River represents a quantitatively important terrestrial carbon pool exported to Laptev Sea
17 sediments (next to POM derived from coastal erosion). Its fate in a future warming Arctic, i.e.
18 its remobilization and remineralization after permafrost thawing as well as its transport
19 pathways to and sequestration in marine sediments is currently under debate. We present one
20 of the first radiocarbon (¹⁴C) data sets for surface water POM within the Lena Delta sampled
21 in summers 2009-2010 and spring 2011 (n=30 samples). The bulk $\Delta^{14}\text{C}$ values varied from –
22 55 to –391‰ translating into ¹⁴C ages of 395 to 3920 years BP. We further estimated the
23 fraction of soil-derived POM to our samples based on 1) particulate organic carbon to
24 particulate nitrogen ratios (POC:PN) and 2) on the stable carbon isotope ($\delta^{13}\text{C}$) composition
25 of our samples. Assuming that this phytoplankton POM has a modern ¹⁴C concentration we
26 inferred the ¹⁴C concentrations of the soil-derived POM fractions. The results ranged from –
27 322 to –884 ‰ (i.e. 3,060 to 17,250 ¹⁴C years BP) for the POC:PN-based scenario and from –
28 261 to –944 ‰ (i.e. 2,370 to 23,100 ¹⁴C years BP). Despite the limitations of our approach,
29 the estimated $\Delta^{14}\text{C}$ values of the soil-derived POM fractions seem to reflect the heterogeneous
30 ¹⁴C concentrations of the Lena River catchment soils covering a range from Holocene to

1 Pleistocene ages better than the bulk POM $\Delta^{14}\text{C}$ values. We further used a dual-carbon
2 isotope three end-member mixing model to distinguish between POM contributions from
3 Holocene soils and Pleistocene Ice Complex deposits to our soil-derived POM fraction. Ice
4 Complex contributions are comparatively low (mean of 0.14) compared to Holocene soils
5 (mean of 0.32) and riverine phytoplankton (mean of 0.55), which could be explained with the
6 restricted spatial distribution of Ice Complex deposits within the Lena catchment. Based on
7 our newly calculated soil-derived POM $\Delta^{14}\text{C}$ values, we propose an isotopic range for the
8 riverine soil-derived POM end-member with $\Delta^{14}\text{C}$ of $-495 \pm 153\text{‰}$ deduced from our $\delta^{13}\text{C}$ -
9 based binary mixing model and $\delta^{13}\text{C}$ of $-26.6 \pm 1\text{‰}$ deduced from our data of Lena Delta
10 soils and literature values. These estimates can help to improve the dual-carbon-isotope
11 simulations used to quantify contributions from riverine soil POM, Pleistocene ice complex
12 POM from coastal erosion, and marine POM in Siberian shelf sediments.

13

14 **1 Introduction**

15 Huge amounts of soil organic carbon are currently stored frozen in permafrost soils of the
16 high northern latitudes (e.g. Tarnocai et al., 2009; Zimov et al., 2009) and excluded from
17 biogeochemical cycling. Due to recent observed and projected amplified warming of the
18 Arctic (ACIA, 2005; Serreze et al., 2000) carbon cycling and the fate of organic carbon
19 released from permafrost soils have received growing attention (e.g. Guo et al., 2007;
20 McGuire et al., 2009; Schuur et al., 2008; 2009; Zimov et al., 2006).

21 Increasing permafrost temperatures, increasing thaw depth in summer (active layer depth),
22 increasing river runoff (Boike et al., 2013; McClelland et al., 2012; Peterson et al., 2002), and
23 increasing length of the open water season (Markus et al., 2009) affecting coastal erosion of
24 permafrost deposits will likely lead to enhanced mobilization and export of old, previously
25 frozen organic matter (OM) to the Arctic shelf seas. The understanding of the different
26 terrestrial OM sources (e.g. fresh vegetation, surface soils, Pleistocene Ice Complex), their
27 age and quality has significantly improved over the last decade (e.g. Guo et al., 2007; Vonk et
28 al., 2010). The use of carbon isotopes ($\delta^{13}\text{C}$, $\Delta^{14}\text{C}$) of dissolved and particulate organic matter
29 as well as individual biomarkers has helped characterizing and distinguishing these different
30 carbon pools, e.g. old, yet little degraded Pleistocene ice complex-derived OM and
31 comparatively younger and more degraded fluvial OM reaching the Siberian shelf seas (Feng
32 et al., 2013; Guo et al., 2004; Gustafsson et al., 2011; Karlsson et al., 2011; Vonk et al., 2012;
33 2010).

1 However, particularly in Siberia ^{14}C data on riverine suspended particulate organic matter
2 (POM) are only sparsely available. A recently published dataset from the Arctic Great Rivers
3 Observatory (A-GRO, www.arcticgreatrivers.org, published 10 January 2015) provides POM
4 ^{14}C data for the Lena River from Zhigansk, approximately 900km upstream of the delta. To
5 our knowledge the only additional POM ^{14}C concentrations sampled directly in Siberian
6 rivers are from the Lena River (unpublished in Vonk et al., 2010) and the Kolyma River
7 (supplementary data of Vonk et al., 2012). Available POM ^{14}C concentrations for Siberia are
8 from offshore the deltas of the Lena (Karlsson et al., 2011) and Kolyma Rivers (Vonk et al.,
9 2010) and inferred from a sediment core taken in a floodplain lake of the Ob' River (Dickens
10 et al., 2011). Due to settling of POM and marine primary production fueled by the riverine
11 nutrients, the ^{14}C concentrations of samples taken off the river mouths are already altered
12 from the "original" river signal. In contrast to Siberia, there are detailed studies on riverine
13 POM ^{14}C concentrations in the Yukon and Mackenzie Rivers in the North American Arctic
14 (Goñi et al., 2005; Guo et al., 2007; Guo and Macdonald, 2006). Here, the POM was found to
15 be significantly older than the dissolved organic matter (DOM) of these rivers and interpreted
16 to be derived from riverbank erosion and thawing permafrost soils compared to a modern
17 vegetation source of DOM (Guo et al., 2006, 2007). Against the backdrop of a warming
18 Arctic (IPCC 2013, ACIA, 2005) and the projected release of old OM in the future
19 presumably as POM rather than DOM (Guo et al., 2007), it is important to assess the age
20 heterogeneity carried by riverine POM and sequestered in the nearshore zone today. This will
21 be an important benchmark to distinguish catchment related changes caused by increasing
22 temperatures from the natural variability of the river system.

23 In contrast to sedimentary OM, POM provides limited spatial and temporal snapshots of its
24 OM properties. However, it has been shown that riverine POM in arctic rivers carries an
25 integrated signal from their permafrost watersheds representing the watershed environmental
26 characteristics (e.g. Goñi et al., 2000; Lobbes et al., 2000; Vonk and Gustafsson, 2009;
27 Winterfeld et al., 2015). Despite the fact that Lena River POM flux is an order of magnitude
28 smaller than its DOM flux it is more likely to transport the climate change signal from
29 permafrost soils of the river catchment (Guo et al., 2007). Also, it has been proposed that the
30 POM pool could be as important as the DOM pool for arctic carbon cycling, because of its
31 possibly high degradation rates in the water column compared to DOM (Sánchez-García et
32 al., 2011; van Dongen et al., 2008).

33 Here we present the first part of a study on particulate OM in the Lena Delta, Siberia
34 (Winterfeld et al. 2015, companion paper). Our POM samples taken in three consecutive

1 years (2009-2011) in the spring and summer seasons add up to the existing data on elemental
2 composition, stable carbon isotopes ($\delta^{13}\text{C}$), and radiocarbon (^{14}C) values as well as provide a
3 first POM ^{14}C data set covering three consecutive years in the Lena Delta. Because riverine
4 and marine POM concentrations are usually too low for source specific biomarker ^{14}C
5 analysis, the available ^{14}C data is from bulk OM. This could result in a considerable age bias
6 depending on the contribution of phytoplankton OM with a rather enriched (modern) ^{14}C
7 concentration to the individual samples. We used different approaches to estimate the fraction
8 of soil and plankton-derived OM in our POM samples and estimated the ^{14}C concentration for
9 the soil-derived fraction of POM transported by the Lena River in summer and spring.
10 Further, we used a dual-carbon isotope three end-member mixing model according to Vonk et
11 al. (2010, 2012) to distinguish not only between plankton- and soil-derived OM, but also
12 between OM from Holocene soils and Pleistocene Ice Complex deposits. The estimated ^{14}C
13 concentrations of soil-derived POM will further help to define the typical isotopic signature of
14 river POM more accurately for modeling riverine OM contributions to Laptev Sea shelf
15 sediments.

16

17 **2 Material and Methods**

18 **2.1 Study Area**

19 A detailed description of the Lena River watershed and Lena Delta can for example be found
20 in the companion paper of this study dealing with the lignin composition of OM in the Lena
21 Delta (Winterfeld et al., 2015).

22 In short, the Lena River is one of the largest Russian Arctic rivers draining a watershed of
23 $\sim 2.46 \times 10^6 \text{ km}^2$ in central Siberia into the Laptev Sea. Continuous permafrost makes up
24 about 72-80% of the drainage area (Amon et al., 2012; Zhang et al., 2005) storing huge
25 amounts of old OM. The permafrost acts as a water impermeable layer and thus affects the
26 regional hydrology and hydrochemistry. The Lena River water discharge and related
27 dissolved and particulate load discharge are highest during spring ice-breakup and snow melt
28 in late May to June while summer and winter discharges are lower (Rachold et al., 2004). The
29 mean annual water discharge is $\sim 588 \text{ km}^3$ for the years 1999 to 2008 (Holmes et al., 2012).
30 Corresponding annual sediment, dissolved organic carbon (DOC), and particulate organic
31 carbon (POC) fluxes are 20.7 Tg/yr (Holmes et al., 2002), 5.7 Tg/yr (Holmes et al., 2012),
32 and 1.2 Tg/yr respectively (Rachold and Hubberten, 1999). A second major source for

1 terrigenous OM delivered to the Laptev Sea is the thermal erosion of ice- and OM-rich
2 Pleistocene ice complex deposits along the coast (see Gustafsson et al., 2011; Mueller-Lupp
3 et al., 2000; Rachold and Hubberten, 1999; Rachold et al., 2004). Recently, it has been shown
4 that the annual supply of total organic carbon from ice complex deposits along the Laptev Sea
5 coast by erosion is ~ 0.66 Tg/yr (Günther et al., 2013).

6 The Lena River Delta is the largest Arctic delta ($\sim 32,000$ km²). It is characterized by a
7 polygonal tundra landscape with active floodplains and it can be divided into three
8 geomorphological terraces (Grigoriev, 1993; Schwamborn et al., 2002). The first terrace
9 includes active floodplains that were formed during the Holocene and makes up about 55% of
10 the total delta area (Morgenstern et al., 2008) covering the central and eastern part. Within
11 the first delta terrace remains of a Pleistocene accumulation plain, also called Ice Complex or
12 Yedoma deposits, form the third terrace covering about 6% of the total delta area
13 (Morgenstern et al., 2008). Sandy islands forming the second terrace cover the rest of the
14 delta in the west. Water and sediment discharge are not equally distributed through the several
15 delta channels. Approximately 80-90% of the total water and up to 85% of the sediment
16 discharge are delivered through the three main eastern channels to the Buor Khaya Bay east
17 of the delta (Fig. 1B), i.e. through the Sardakhsko-Trofimovskaya channel system (60-75%
18 water, 70% sediment) and the Bykovskaya channel (20-25% water, 15% sediment). Only a
19 minor portion is discharged to the north and west through the Tumatskaya and Olenyokskaya
20 channels (5-10% water, 10% sediment) (Charkin et al., 2011 and references therein; Ivanov
21 and Piskun, 1999).

22 **2.2 Sampling**

23 The sampling sites presented in this study are located in the eastern part of the Lena Delta and
24 adjacent Buor Khaya Bay (Table 1, Fig. 1B) in and along the channels of highest discharge.
25 Permafrost soil samples from the first delta and surface water total suspended matter (TSM)
26 were collected during three expeditions in August 2009, July/August 2010, and in late May
27 and late June/early July 2011. All soil samples were taken from riverbank bluffs of the first
28 delta terrace (Holocene formation), which is elevated (5-16m) over the active floodplains. The
29 soil profiles vary strongly in sediment composition and OM content. Within the profiles
30 sandy layers derived from extreme flooding events (Schwamborn et al., 2002) and aeolian
31 input (Kutzbach et al., 2004; Sanders, 2011) alternate with buried surface soil layers and peat
32 layers rich in fibrous plant and root detritus in different stages of decomposition. The peat
33 layers are either of autochthonous or of allochthonous origin. Allochthonous material is

1 eroded from river banks further upstream and re-deposited in the delta. In order to obtain
2 samples that reflect the original state of the frozen permafrost soils, we removed the thawed
3 soil material from each riverbank bluff for its total height with a spade. Frozen pieces of soil
4 were then excavated at different depths using hatchet and hammer.

5 Suspended particulate matter of Lena River surface water was sampled at different stations in
6 the main river channels of the delta on the Russian vessel Puteyski 405 (Fig. 1B, Table 1)
7 from the upper 0.5m of the water column. In the smaller delta channels the samples were
8 taken approximately in the middle of the channel. Because the main delta channels can be
9 >1km in width, we sampled a couple of hundred meters off the shore with water depth of
10 >10m, but not in the middle of the channel. Three samples (19, 35, 36; Fig. 1B) were taken
11 outside the delta in shallow water depth. We discuss these samples as “delta samples”,
12 because the surface water at these sampling locations is outflowing Lena River water as
13 shown by temperature and salinity profiles by Semiletov et al. (2011) and Kraberg et al.
14 (2013). Between 1 and 30 L of water were filtered on pre-combusted (4.5h at 450°C) and pre-
15 weighed glass fiber filters (GF/F Whatman, 0.7µm membrane) for particulate organic carbon
16 (POC) and nitrogen (PN) analysis as well as carbon isotope analysis. Additionally, one water
17 sample of 20 L from the spring freshet in 2011 was stored cooled in opaque canisters for
18 several days to allow for the suspended matter to settle. Before decanting the supernatant
19 water it was filtered on pre-combusted and pre-weighed GF/F filters to check for the SPM
20 remaining in suspension. For this sample (sample ID 37) the SPM of the supernatant water
21 represented 0.1 % of the settled material on a dry weight basis and therefore the loss of
22 material in suspension can be neglected.

23 The soil samples were stored in pre-combusted glass jars (4.5h at 450°C) and GF/F filters
24 were either stored in pre-combusted petri dishes (Ø 47mm) or wrapped in pre-combusted
25 aluminum foil. All samples were kept frozen at -20°C during storage and transport until
26 analysis.

27 **2.3 Laboratory analyses**

28 Soil and sediment samples were freeze-dried, homogenized, and subsampled for elemental
29 analysis. All filters were oven-dried at 40°C for 24h.

30 **2.3.1 Elemental analyses**

31 Weight percent organic carbon (OC) and total nitrogen (TN) content of soil samples were
32 determined by high temperature combustion after removal of carbonates as described by Goñi

1 et al. (2003). TSM samples were analyzed for OC and TN at the Alfred Wegener Institute in
2 Bremerhaven, Germany, using the same protocol. Every 10 samples control standards were
3 analyzed to constrain the analytical uncertainty of 0.1%.

4 **2.3.2 Carbon isotope analysis ($\Delta^{14}\text{C}$, $\delta^{13}\text{C}$)**

5 Samples were radiocarbon-dated at the National Ocean Sciences Accelerator Mass
6 Spectrometry (NOSAMS) facility at Woods Hole Oceanographic Institution, USA. Bulk
7 sediment samples and filters with TSM were submitted unprocessed and inorganic carbon was
8 removed during sample preparation at NOSAMS. The radiocarbon analyses at NOSAMS
9 were carried out using standard methods (McNichol et al., 1994). Results are reported as
10 $\Delta^{14}\text{C}$, conventional radiocarbon ages (years BP), and fraction modern carbon (*fMC*) including
11 the correction for isotope fractionation (Stuiver and Polach, 1977).

12 The stable carbon isotope composition ($\delta^{13}\text{C}$) was measured on splits of the CO_2 gas of the
13 samples generated prior to graphite reduction at NOSAMS using a VG Optima IRMS. Results
14 are reported in per mil (‰) relative to VPDB.

15 **2.4 End-member modeling**

16 The relative source contributions (phytoplankton and soil) to the POM samples are estimated
17 by solving linear two end-member (using POC:PN and $\delta^{13}\text{C}$ as parameters) and dual-carbon
18 isotope ($\delta^{13}\text{C}$, $\Delta^{14}\text{C}$) three end-member mixing models with end-members determined from
19 own data and the literature. The end-member values used in the different modeling
20 approaches are given in Table 4. Source data for the calculation of the POC:PN soil end-
21 member as well as the $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ end-members for Holocene soil are given in Tables S1-3
22 in the supplement.

23 To account for the uncertainty of the measured values, we assume independent, normally
24 distributed uncertainties for the observed values with a standard deviation characterizing the
25 measurement uncertainty. For the end-members we assume a normal distribution using the
26 standard deviations from the observed samples on which the end-members are based on.

27 Uncertainty in the resulting contributions of phytoplankton and soil are estimated in a Monte
28 Carlo approach similar to Vonk et al. (2010, 2012) and Karlsson et al. (2011). The source
29 fractions are estimated 100,000 times, each time drawing the end-members as well as the
30 observed values from their distributions. Solutions with negative fractions are omitted and the
31 mean and the standard deviation are reported.

32

1 **3 Results**

2 **3.1 Elemental composition**

3 The organic carbon (OC) and total nitrogen (TN) concentrations of the first terrace soil
4 samples can be found in Tables 3 and S3 in the companion paper Winterfeld et al. (2015).

5 The surface water POC concentrations within the delta showed a high spatial and interannual
6 variability similar to the TSM concentrations of the respective samples. The mean POC
7 concentration for August 2009 was 1.21 mg/L (n=21, range 0.35-7.24 mg/L) and
8 corresponding POC content was 7.2 wt% (range 1.9-37.7 wt%, Table 2 and Table S1). The
9 POC contents for July/August 2010 and June/July 2011 were lower than in 2009 with mean
10 concentrations of 0.57 mg/L (n= 13, 0.15-1.30 mg/L) and 3.1 wt% (1.4-4.7 wt%) as well as
11 0.74 mg/L (n=9, 0.29-1.51 mg/L) and 4.3 wt% (3.2-5.0 wt%), respectively. The single sample
12 from late May 2011 (sample ID 37) showed highest POC concentration per liter (8.2 mg/L) of
13 all presented samples with a related POC content of 1.7 wt%. Our POC data are well within
14 the range of values reported for the Lena Delta before (Cauwet and Sidorov, 1996; Rachold
15 and Hubberten, 1999; Semiletov et al., 2011). The two samples from the Buor Khaya Bay
16 surface waters showed the lowest POC concentrations per liter, i.e. 0.37 mg/L (sample 35)
17 and 0.15 mg/L (sample 36) with corresponding 4.4 and 1.5 wt% POC, respectively (Table 2
18 and S4 supplement). The considerable drop of POC (and TSM) concentrations offshore the
19 delta is due to flocculation and settling of TSM in the zone of fresh and salt water mixing (e.g.
20 Lisitsyn, 1995) and was also observed during other years of sampling (e.g. Cauwet and
21 Sidorov, 1996; Semiletov et al., 2011).

22 The atomic particulate organic carbon (POC) to particulate nitrogen (PN) ratios (POC:PN) of
23 samples taken in summer 2009 were slightly higher than for summer 2010 samples with mean
24 values of 9.6 (n=20, 6.8-19.3) and of 8.0 (n=13, 5.0-10.3, Table 2 and S4), respectively. The
25 POC:PN ratios of samples taken in June/July 2011 were rather similar to the July/August
26 samples with a mean of 7.8 (n=9, 5.9-9.7). The sample from late May 2011 had a POC:PN
27 ratio of 7.5.

28 **3.2 Carbon isotope inventories**

29 The stable carbon ($\delta^{13}\text{C}$) and radiocarbon (^{14}C) results are shown in Table 3. The radiocarbon
30 data presented here will predominantly be discussed in terms of $\Delta^{14}\text{C}$ in per mil (‰).

1 Additionally, the fraction modern carbon (*fMC*) and ^{14}C ages in years before present (yrs BP)
2 are given in Table 3.

3 **3.2.1 Stable carbon isotope composition ($\delta^{13}\text{C}$)**

4 The two soil profiles from the first delta terrace showed $\delta^{13}\text{C}$ values between -27.0‰ and $-$
5 25.1‰ with a mean of -26.1‰ , ($n = 7$, Table 3), which is within the range observed for
6 Holocene soils in the delta (e.g. Schirrmeister et al., 2011 and references therein). Similar to
7 the POC contents, the Lena Delta surface water POM $\delta^{13}\text{C}$ values varied strongly spatially
8 and annually (Fig. S1 supplement). POM from August 2009 showed more depleted $\delta^{13}\text{C}$
9 values compared to the other years, ranging from -34.2‰ to -28.8‰ (mean value = -30.4‰ ,
10 $n = 13$). July/August 2010 and June/July 2011 POM isotopic compositions ranged from $-$
11 30.4‰ to -28.3‰ (mean value = -29.3‰ , $n = 13$) and from -29.3‰ to -28.3‰ (mean value
12 = -28.7‰ , $n = 3$), respectively. The isotopically most enriched POM $\delta^{13}\text{C}$ value of -26.5‰
13 was determined for the sample from late May 2011 (Table 3). The $\delta^{13}\text{C}$ of Buor Khaya Bay
14 surface water POM in August 2010 could only be determined for one of the samples, i.e.
15 sample 36 with -30.4‰ .

16 **3.2.2 Radiocarbon (^{14}C) concentration**

17 The $\Delta^{14}\text{C}$ values of the two soil profiles decreased with depth from -197 to -377‰ for the
18 riverbank profile L09-12 and from -204 to -466‰ for profile L09-28 (Table 3, Fig. 3A). The
19 corresponding ^{14}C ages for both profiles together ranged from 1,710 to 4,900 yrs BP. Within
20 profile L09-12 on Samoylov Island an age reversal was observed for the two oldest samples
21 (Table 3), which most likely is due to allochthonous material that was transported to the delta
22 from an upstream location. The same age reversal on Samoylov Island was also observed by
23 Kuptsov and Lisitsin (1996). Overall, our $\Delta^{14}\text{C}$ values reflect the late Holocene formation of
24 these soils and fit within the range of ages determined for the Lena Delta first terrace
25 (Bolshiyarov et al., 2015; Kuptsov and Lisitsin, 1996; Schwamborn et al., 2002).

26 As with other TSM parameters, the POM $\Delta^{14}\text{C}$ values showed strong spatial and interannual
27 variability (Fig. 2, panels Q-T and Fig. S1). Lena Delta POM ^{14}C concentrations varied from
28 -262‰ to -55‰ in August 2009 (mean of -160‰ , $n=13$), from -391‰ to -143‰ in
29 July/August 2010 (mean of -194‰ , $n=13$), and from -154‰ to -144‰ in June/July 2011
30 (mean of -150‰ , $n=3$). The sample from late May 2011 showed a ^{14}C concentration of $-$
31 306‰ and the Buor Khaya Bay surface samples of -176‰ (sample 35) and -143‰ (sample
32 36, Table 3, Fig. 2R-S). Overall these ^{14}C concentrations covered a range of ^{14}C ages from

1 395 to 3,920 yrs BP. The samples with the lowest $\Delta^{14}\text{C}$ values of -262‰ (sample 1) and $-$
2 391‰ (sample 31) were taken close to the Pleistocene Ice Complex deposits, which likely
3 contributed to the local POM in the Lena River surface water.

4

5 **4 Discussion**

6 **4.1 Origin of organic matter in the Lena Delta**

7 Riverine particulate organic matter consists of a heterogeneous mixture derived from two
8 major sources, i.e. terrestrial (e.g. fresh vegetation and litter, surface and deep soils horizons)
9 and aquatic (phytoplankton/bacterial primary production). The terrestrial OM in the Lena
10 River catchment can further be differentiated into two pools of different age: the late
11 Pleistocene organic-rich Ice Complex or Yedoma deposits, particularly in the lowlands (0-
12 400m elevation, e.g. Grosse et al., 2013) and the Holocene permafrost soils. POC:PN ratios as
13 well as $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ values of bulk OM can be used to estimate terrestrial and aquatic
14 contributions (e.g. Hedges and Oades, 1997). However, due to overlaps in soil/plant and
15 algal/bacterial signatures it might be difficult to unambiguously differentiate between
16 terrestrial and aquatic sources.

17 Our POC:PN ratios from the summers 2009 and 2010 as well as spring 2011 vary largely
18 throughout the delta (Table 2 and S4) similar to the TSM and lignin phenol concentrations
19 sampled during the same field trips (Winterfeld et al. 2015, companion paper). The ratios
20 range from 3.7 to 19.3 for all samples and seasons with mean atomic POC:PN ratios of 9.6
21 (2009), 7.6 (2010), and 7.8 (2011). Low POC:PN ratios, i.e. ~ 6 generally indicate high
22 contributions from phytoplankton and/or bacterial primary production while ratios >20 are
23 indicative of soil and plant contributions (e.g. Hedges et al., 1997; Meyers and Lallier-Vergés,
24 1999). Based on these end-members, our data from the summer and spring seasons would
25 suggest a considerable fraction of primary production OM to be present in our samples.

26 However, due to possible sorption of inorganic nitrogen to clay minerals (Schubert and
27 Calvert, 2001) our calculated POC:PN ratios might be too low, underestimating the soil-
28 derived OM fraction. This will be discussed in more detail in section 4.3.1. Another
29 possibility for lower, but mainly soil derived POC:PN ratios could be the selective
30 degradation of labile OM compared to total nitrogen (Kuhry and Vitt, 1996).

31 Analogous to the POC:PN ratios, the $\delta^{13}\text{C}_{\text{POM}}$ values point to a considerable contribution of
32 primary production OM to our samples from 2009-2011. The $\delta^{13}\text{C}_{\text{POM}}$ values of our samples
33 taken in 2009-2011 vary over a broad range (-34.2 to -26.5‰ , Table 3), which is similar to

1 $\delta^{13}\text{C}_{\text{POM}}$ values previously published by Rachold and Hubberten (1999) for the Lena Delta
2 and Lena River upstream the delta (-31.3 to -25.7‰ , July/August 1994/95), by A-GRO
3 (www.arcticgreatrivers.org) $\sim 900\text{km}$ upstream the Lena Delta at Zhigansk (-30.3 to -25.2‰ ,
4 May-August 2004-2010), and by Semiletov et al. (2011) for the Lena Delta and Lena River ($-$
5 30.0 to -25.0‰ , August-September 1995-2008).

6 In general, the more enriched $\delta^{13}\text{C}_{\text{POM}}$ values (around -27‰) reflect the dominant
7 contribution from C3 plants and soils (e.g. Hedges et al., 1997) from the river catchment. The
8 more depleted $\delta^{13}\text{C}_{\text{POM}}$ values ($< -29\text{‰}$) point to mixing with riverine plankton utilizing
9 dissolved inorganic carbon (DIC) with depleted $\delta^{13}\text{C}$ signatures as suggested for the Lena
10 River (Alling et al., 2012; Rachold and Hubberten, 1999).

11 The total flux of primary production OM in the Lena River is thought to be negligible due to
12 low light penetration in the turbid waters (Cauwet and Sidorov, 1996; Sorokin and Sorokin,
13 1996). Yet, the surface water layer from which we took our TSM samples is characterized by
14 an abundance of riverine plankton (Kraberg et al., 2013; Sorokin and Sorokin, 1996), which
15 could explain the small soil-derived OM fraction.

16 In chapter 4.3 we present the results of two binary and one three end-member mixing model
17 to estimate the soil OM contribution to our POM samples and to further calculate the ^{14}C
18 concentration of the soil fraction.

19 **4.2 ^{14}C and age heterogeneity of POM ($^{14}\text{C}_{\text{POM}}$) in the Lena Delta**

20 Terrestrial POM enters a river predominantly by physical weathering of adjacent soils
21 (Raymond and Bauer, 2001 and references therein). Compared to vegetation utilizing modern
22 atmospheric $^{14}\text{CO}_2$, the bulk POM of soil is pre-aged. The specific residence time of POM in
23 the soil before entering the river depends on various environmental factors like humidity,
24 temperature, topography, soil type, size and topography of the catchment area (e.g. Kusch et
25 al., 2010; Oades, 1988; Raymond and Bauer, 2001; Trumbore, 2009, 1993). Furthermore, the
26 fluvial transport of POM (and TSM) is governed by hydrological characteristics like runoff,
27 discharge and flow velocity, sedimentation along riverbanks and floodplains as well as
28 resuspension of deposited material. Therefore, the age of terrestrial POM is a combination of
29 its residence time within the soil plus its residence time within the river basin, which can
30 differ substantially for different terrestrial POM fractions (lipids versus lignin) from arctic
31 watersheds (e.g. Feng et al., 2013; Gustafsson et al., 2011).

32 The Lena Delta and Buor Khaya Bay surface water $^{14}\text{C}_{\text{POM}}$ concentrations presented here are
33 depleted with respect to the current atmospheric $^{14}\text{CO}_2$ (Table 3). The $\Delta^{14}\text{C}$ values range from

1 -391 ‰ to -55 ‰ for 2009 to 2011 translating into ^{14}C ages >400 yrs and up to 3,920 yrs BP
2 for samples taken close to the Pleistocene Ice Complex deposits of Kurungnakh Island (Fig. 2,
3 panels Q-T, Table 3). These results are within the range of reported $\Delta^{14}\text{C}$ values for surface
4 water POM offshore the Lena Delta and influenced by Lena River outflow (Karlsson et al.,
5 2011). Based on these results it seems reasonable to assume that a large fraction of Lena Delta
6 POM originates from physical weathering of relatively young Holocene soils (active layer) of
7 the first delta terrace and south of the delta.

8 However, soils outcropping along the Lena River south of the delta can be substantially older
9 than late Holocene ages (Kuptsov and Lisitsin, 1996) including some areas of Pleistocene Ice
10 Complex deposits (Grosse et al., 2013). Also, OM within the active layer and shallow
11 permafrost table can be as old as 3,000 yrs BP in the Lena Delta (30 cm below surface, Höfle
12 et al., 2013) or more than >10,000 yrs BP south of the delta (Kuptsov and Lisitsin, 1996). As
13 shown by the lignin phenol composition of Lena Delta POM (Winterfeld et al., 2015,
14 companion paper) approximately half of the surface water POM is derived from the
15 catchment south of the delta with considerable contributions from delta soils, particularly in
16 the summer season when riverbank erosion is strongest. Considering that, we would expect
17 generally older POM ^{14}C ages. Additionally, riverbank erosion contributes POM covering the
18 ^{14}C age range of the whole soil profile, not only from the active layer.

19 One possible explanation for our relatively young POM ^{14}C ages could be the contribution of
20 plankton-derived OM with a rather modern ^{14}C concentration concealing the “true” age of
21 soil-derived OM. Phytoplankton-derived OM contribution was also suggested to be the reason
22 for relatively young POM from the Ob’ River inferred from a core of a floodplain lake
23 (Dickens et al., 2011). Although the overall contribution and flux of autochthonous
24 phytoplankton OM in the Lena River is rather small or even negligible due to the high
25 turbidity and low light penetration (Cauwet and Sidorov, 1996; Sorokin and Sorokin, 1996),
26 phytoplankton can be quite abundant in the surface water (Kraberg et al., 2013; Sorokin and
27 Sorokin, 1996), which we sampled for our POM analyses. In the following section 4.3 we
28 present results from two different approaches to quantify the soil OM fraction in our samples
29 and further estimate its ^{14}C concentration based on the assumption of plankton-derived OM
30 with modern $\Delta^{14}\text{C}$ values.

1 4.3 Quantitative POM source determination and soil ¹⁴C concentrations

2 4.3.1 Binary mixing model scenario 1

3 POC:PN ratios around 6 are usually associated with OM derived from algal/bacterial primary
4 production and higher ratios of >20 with OM derived from soils (Hedges et al., 1997; Meyers
5 and Lallier-vergés, 1999 and references therein). However, as noted above (section 4.1)
6 adsorption of inorganic nitrogen derived from OM decomposition (e.g. ammonium) to clay
7 minerals (Schubert and Calvert, 2001), which is not accounted for when determining the total
8 PN content, may additionally affect the POC:PN ratio in TSM leading to lower values than
9 would be expected from mixing of the two end-members alone. Likewise, selective
10 degradation of labile organic carbon (Kuhry and Vitt, 1996) would also result in lower
11 POC:PN ratios. Both processes would lead to low estimates of the soil-derived OM
12 contribution and suggest a higher contribution from plankton. Both explanations were also
13 suggested by Sánchez-García et al. (2011) for POM in the Laptev Sea offshore the Lena Delta
14 with unusually low POC:PN ratios.

15 In order to estimate the inorganic nitrogen content for our sample sets from each year, we
16 used the intercept of the POC versus PN content regression line at POC = 0 (Fig. S2). By
17 subtracting these amounts from the analyzed total PN content of the respective samples, we
18 could calculate new soil POC:PN ratios (POC:PN_{NEW}) for our samples (Table S4
19 supplement). Based on these POC:PN_{NEW} ratios (and their uncertainty, derived from the
20 standard error of the POC versus PN regressions), we calculated the soil-derived fraction
21 within our POM samples using a simple two end-member mixing model as following:

$$22 \text{ POC:PN}_{\text{NEW}} = f_{\text{soil}} \times \text{POC:PN}_{\text{soil}} + f_{\text{plankton}} \times \text{POC:PN}_{\text{plankton}} \quad (1)$$

$$23 \text{ and } 1 = f_{\text{soil}} + f_{\text{plankton}} \quad (2)$$

24 where POC:PN_{NEW} is the corrected value of the POM sample (Table S4). As the end-member
25 for POC:PN_{soil} we chose 23.7 ± 11 (Table 4 and S1 supplement), which is an average
26 calculated from Lena Delta first terrace soils presented in Winterfeld et al. (2015, companion
27 paper) and delta soils as well as soil from the Lena River watershed covering the taiga to
28 tundra transition from Höfle et al. (2013), Zubrzycki (2013), and Zubrzycki et al. (2012,
29 individual values in Table S1 supplement). The POC:PN_{plankton} end-member value is 6 ± 1
30 (Table 4, e.g. Meyers, 1994).

31 The calculated soil-derived OM fractions of Lena Delta POM varied from 0.26 to 0.70 (mean
32 of 0.35, n=21, Table 5) for summer 2009, from 0.26 to 0.44 (mean of 0.34, n=11) in summer

1 | 2010, and from 0.39 to 0.50 (mean of 0.43, n=9) for late June/early July 2011 (Table 5). We
 2 | used the POC versus PN (wt%) regression line from the summer 2010 samples within the
 3 | delta to correct the two samples taken outside of the delta in the Buor Khaya Bay. They had
 4 | calculated soil fractions of 0.39 (sample 35) and 0.12 (sample 36). The same was done for the
 5 | single sample from late May 2011. We used the regression line from the samples taken 4
 6 | weeks later in June/July and the soil fraction of sample 37 was 0.13 (Table 5). Note that these
 7 | soil- and plankton-derived OM fractions can only serve as rough estimates. Without
 8 | determining the particulate organic nitrogen directly for every sample our POC:PN_{NEW} ratios
 9 | (Table S4) might be highly over- and underestimating OM fractions in individual samples.

10 | The calculated soil and plankton OM fractions (f_{soil} and f_{plankton} , Table 5) were further used in
 11 | an isotopic mass balance to determine the ^{14}C concentration of the soil fraction assuming the
 12 | plankton-derived OM is modern ($\Delta^{14}\text{C}_{\text{plankton}} = 41.9 \pm 4.2\text{‰}$, Table 4):

$$13 \quad f_{\text{POM}} \times \Delta^{14}\text{C}_{\text{POM}} = f_{\text{soil}} \times \Delta^{14}\text{C}_{\text{soil}} + f_{\text{plankton}} \times \Delta^{14}\text{C}_{\text{plankton}} \quad (3)$$

$$14 \quad \text{and } f_{\text{POM}} = f_{\text{soil}} + f_{\text{plankton}} \quad (4)$$

15 | where f_{POM} , f_{soil} , and f_{plankton} are the fractions of POM, soil- and plankton-derived OM and
 16 | $\Delta^{14}\text{C}_{\text{POM}}$, $\Delta^{14}\text{C}_{\text{soil}}$, and $\Delta^{14}\text{C}_{\text{plankton}}$ are the $\Delta^{14}\text{C}$ values of these sources. As noted above, $41.9 \pm$
 17 | 4.2‰ is assumed as a maximum estimate for $\Delta^{14}\text{C}_{\text{plankton}}$ based on atmospheric CO_2 $\Delta^{14}\text{C}$
 18 | values for May to August 2009-2011 from the Schauinsland observatory, Germany.

19 | The results of the newly calculated soil $\Delta^{14}\text{C}$ values using POC:PN_{NEW} ratios ($\Delta^{14}\text{C}_{\text{POC:PN}}$) to
 20 | partition between soil- and plankton-derived OM are shown in Table 5. The soil $\Delta^{14}\text{C}_{\text{POC:PN}}$
 21 | values range from -884‰ to -322‰ for the sampling period of 2009-2011 translating into
 22 | soil ^{14}C ages $>3,000$ yrs BP with an average of 6,700 yrs BP (Table 5). Analogous to the two
 23 | comparatively old bulk $^{14}\text{C}_{\text{POM}}$ ages off Kurungnakh Island taken in 2009 and 2010 (Table 3),
 24 | the calculated $^{14}\text{C}_{\text{POC:PN}}$ age for sample 1 was 17,250 yrs BP and yielded a fossil age ($>50,000$
 25 | years BP) for sample 31. Considering that the riverbank outcrops of Kurungnakh Island cover
 26 | an age range of approximately 100 kyrs with organic-rich ice complex deposits of about 50
 27 | kyrs (Wetterich et al., 2008) these ^{14}C ages seem to be realistic.

28 | Again, the uncertainties associated with the contribution of inorganic nitrogen to our total PN
 29 | contents are rather high resulting in a relatively rough estimation of soil and plankton OM
 30 | fractions. These uncertainties are further affecting the calculation of the soil $\Delta^{14}\text{C}_{\text{POC:PN}}$
 31 | concentrations. That means the calculated ^{14}C ages are estimates. Yet, they demonstrate that a
 32 | possible underestimation of soil-derived OM ages can be considerable.

1 **4.3.2 Binary mixing model scenario 2**

2 Similar to the approach discussed in section 4.3.1, we used a second scenario based on $\delta^{13}\text{C}$
3 values to distinguish between soil- and plankton-derived OM in our Lena Delta POM
4 samples. The vegetation in the Lena River catchment (taiga and tundra) is dominated by C3
5 plants with a $\delta^{13}\text{C}$ of around -25‰ to -27‰ (Rachold and Hubberten, 1999). This is also
6 reflected in our $\delta^{13}\text{C}$ data from the first delta terrace soils with an average of -26.2‰ ($n=7$,
7 Table 3). Bird et al. (2002) determined the $\delta^{13}\text{C}$ composition of taiga and tundra soils
8 (excluding peatlands) along Yenisey River on a latitudinal transect. For the binary mixing
9 model we used a soil OM end-member value $-26.6 \pm 1\text{‰}$ (Table 4), which is a combination
10 of $\delta^{13}\text{C}$ data from this study and the literature (Table S2, Bird et al., 2002; Pitkänen et al.,
11 2002; Xu et al., 2009) covering tundra and taiga soils in Siberia and Alaska.

12 The $\delta^{13}\text{C}$ composition of riverine plankton POM depends on the fractionation between
13 phytoplankton and dissolved inorganic carbon (DIC). The distribution of the different DIC
14 fractions (dissolved CO_2 , bicarbonate (HCO_3^-), and carbonate ion (CO_3^{2-})) varies depending on
15 temperature and pH. In the lower reaches of the Lena River and the Lena Delta $>90\%$ of the
16 DIC are made up of bicarbonate (Alling et al., 2012), i.e. the $\delta^{13}\text{C}$ of bicarbonate represents
17 the $\delta^{13}\text{C}$ of DIC. Sources for DIC are generally the CO_2 derived from soil OM degradation,
18 CO_2 released during the dissolution of carbonates, and CO_2 from the atmosphere. The Lena
19 River geochemistry is mainly influenced by carbonate weathering and groundwater in the
20 summer season (Gordeev and Sidorov, 1993). Assuming a fractionation of $-22.5 \pm 2.5\text{‰}$
21 between phytoplankton and DIC (Mook and Tan, 1991) and a $\delta^{13}\text{C}_{\text{DIC}}$ of -8‰ for the Lena
22 Delta (Alling et al., 2012) a plankton $\delta^{13}\text{C}$ end-member value of $-30.5 \pm 2.5\text{‰}$ would be
23 expected. Similar or more depleted $\delta^{13}\text{C}$ values of bicarbonate and phytoplankton POM were
24 also determined in the Yenisey and Ob' Rivers (Galimov et al., 2006) and in temperate
25 estuaries (e.g. Ahad et al., 2008; Chanton and Lewis, 2002). Our most depleted $\delta^{13}\text{C}_{\text{POM}}$ of $-$
26 34.2‰ for a sample from the summer 2009 (Table 3) is even lower than the plankton end-
27 member used here ($\delta^{13}\text{C}_{\text{plankton}} = -30.5\text{‰}$). The sample location is offshore Muostakh Island
28 (Fig. 1B) and influenced by mixing with marine waters, which complicates the DIC
29 composition and processes affecting $\delta^{13}\text{C}$ of DIC (Alling et al., 2012).

30 We used the following two end-member model to estimate the soil- and plankton-derived OM
31 fractions (f_{soil} , f_{plankton}) to our POM samples:

$$32 \delta^{13}\text{C}_{\text{POM}} = f_{\text{soil}} \times \delta^{13}\text{C}_{\text{soil}} + f_{\text{plankton}} \times \delta^{13}\text{C}_{\text{plankton}} \quad (5)$$

$$33 \text{ and } 1 = f_{\text{soil}} + f_{\text{plankton}} \quad (6)$$

1 where $\delta^{13}\text{C}_{\text{POM}}$ is the analyzed $\delta^{13}\text{C}$ value of our POM samples (Table 3), $\delta^{13}\text{C}_{\text{soil}}$ is the soil
2 end-member value of $-26.6 \pm 1\text{‰}$, and $\delta^{13}\text{C}_{\text{plankton}}$ is plankton end-member value of $-30.5 \pm$
3 2.5‰ (Tables 4 and S3 supplement).

4 The calculated soil OM fractions varied from 0.12 to 0.51 in summer 2009 (mean of 0.32,
5 $n=12$, Table 5), from 0.34 to 0.59 in summer 2010 (mean of 0.45, $n=12$), and from 0.44 to
6 0.59 in spring 2011 (mean of 0.53, $n=3$). The Buor Khaya Bay POM sample 21 showed a soil
7 fraction of 0.75 and the spring freshet value (sample 37) a soil fraction of 0.80 (Table 5). As
8 discussed above in Sect. 4.3.1, these soil OM fractions are rough estimates in the absence of
9 direct plankton determination.

10 Furthermore, $\Delta^{14}\text{C}$ values of the soil-derived OM fraction were calculated for the contribution
11 of modern plankton OM as described in Sect. 4.3.1 using the Eq. (3) and (4). Because the soil
12 contributions calculated in this scenario are slightly higher than in the POC:PN-based
13 scenario, the $\Delta^{14}\text{C}$ calculations resulted in less radiocarbon depleted estimates compared to
14 the POC:PN scenario (table 5). Nonetheless, the $\Delta^{14}\text{C}$ values based on the $\delta^{13}\text{C}$ end-member
15 model are considerably ^{14}C -depleted compared to bulk POM ^{14}C concentrations. The
16 estimated $\Delta^{14}\text{C}$ values range from -944‰ to -495‰ for all samples 2009-2011 representing
17 ^{14}C ages from 23,100 to 2,370 yrs BP (Table 5). The oldest samples are, again, the ones taken
18 close to Pleistocene Ice Complex deposits (samples 1 and 31).

19 **4.3.3 Comparison of scenario 1 and 2**

20 Of all samples from 2009-2011 presented here, 28 samples have a soil fraction estimate from
21 both scenarios. For these samples the POC:PN scenario gives a lower mean soil fraction of
22 0.33 compared to 0.43 from scenario 2 (based $\delta^{13}\text{C}$, Fig. S3). The comparison demonstrates
23 that the error estimates determined in the end-member calculation are realistic, as only 6 (2)
24 of 28 samples are outside one (two) standard deviations of the estimated error. As the
25 uncertainty of the estimates is high, both estimates are only weakly correlated (removing the
26 clear outlier sample 37 we get $R=0.3$, $p=0.1$).

27 Because we assumed a modern $\Delta^{14}\text{C}$ value for the phytoplankton OM, the estimated soil ^{14}C
28 concentrations are related to the amount of soil OM calculated in both scenarios. The lower
29 mean fraction in scenario 1 therefore resulted in a lower mean soil $\Delta^{14}\text{C}$ value of -569‰ (^{14}C
30 age = 6,700 year BP, $n= 26$) compared to -495‰ (^{14}C age = 5,430 years BP, $n= 28$) for
31 scenario 2. Besides the spring freshet sample from 2011, the two samples with the lowest bulk
32 $\Delta^{14}\text{C}$ values (sample 1 & 31, Table 3) also showed the one of the lowest estimated soil $\Delta^{14}\text{C}$
33 values, namely -884‰ and radiocarbon-free (fossil) for scenario 1 as well as -944‰ and –

1 754‰ for scenario 2. The two samples were taken close to Ice Complex deposits within the
 2 delta, which illustrates the locally pronounced influence of these deposits. Another sample
 3 standing out is sample 19 taken outside the delta close to Muostakh Island, which is also
 4 composed of Ice Complex deposits (Fig. 1B). Its bulk POM $\Delta^{14}\text{C}$ value was highest ($\Delta^{14}\text{C} = -$
 5 55‰, Table 3) pointing to comparatively young OM and its $\delta^{13}\text{C}$ value was lowest (-34.2‰)
 6 pointing to a rather high contribution of phytoplankton. This is in our line of argumentation
 7 assuming a contribution of plankton-derived OM with a modern $\Delta^{14}\text{C}$ value. Because of our
 8 chosen end-members, the soil fraction in sample 19 was rather small in the ^{13}C -based scenario
 9 and the resulting $\Delta^{14}\text{C}$ value of the soil fraction was with -774‰ (^{14}C age of 11,890 years
 10 BP) the second lowest.

11 In contrast to scenario 1, it is more obvious in scenario 2 that the POM samples taken in late
 12 June/early July 2011 are more enriched in ^{14}C (younger) than the POM samples taken later in
 13 the summer (Aug 2009 and July/Aug 2010). Similar observation were made for DOM $\Delta^{14}\text{C}$
 14 concentrations of the Lena River at Zhigansk ~900km south of the delta (Raymond et al.,
 15 2007) and the Kolyma River in East Siberia (Neff et al., 2006). Their explanation was that
 16 due to the deepening of the active layer in summer older soil layers are accessible for melt
 17 water and groundwater contributing an older DOM signature to the river than in spring when
 18 most soil is still frozen. A comparable scenario could explain estimated $\Delta^{14}\text{C}$ concentration
 19 decreasing from spring freshet to summer. In addition to active layer deepening riverbank
 20 erosion is strongest during the summer and might contribute a considerable amount of soil-
 21 derived OM with a large ^{14}C age range to the Lena Delta surface water.

22 **4.3.4 Holocene soil versus Pleistocene Ice Complex deposits**

23 As an extension of the two end-member model, we applied a dual-carbon isotope ($\delta^{13}\text{C}$, $\Delta^{14}\text{C}$)
 24 three end-member model (after Karlsson et al., 2011; Vonk et al., 2010, 2012) to separate the
 25 source contributions of phytoplankton, Holocene soil and Pleistocene Ice Complex deposits
 26 (ICD) using the following equations:

$$27 \delta^{13}\text{C}_{\text{POM}} = f_{\text{soil_Holocene}} \times \delta^{13}\text{C}_{\text{soil}} + f_{\text{soil_ICD}} \times \delta^{13}\text{C}_{\text{soil}} + f_{\text{plankton}} \times \delta^{13}\text{C}_{\text{plankton}} \quad (7)$$

$$28 {}^{14}\text{C}_{\text{POM}} = f_{\text{soil_Holocene}} \times {}^{14}\text{C}_{\text{soil}} + f_{\text{soil_ICD}} \times {}^{14}\text{C}_{\text{soil}} + f_{\text{plankton}} \times {}^{14}\text{C}_{\text{plankton}} \quad (8)$$

$$29 \text{ and } 1 = f_{\text{soil_Holocene}} + f_{\text{soil_ICD}} + f_{\text{plankton}} \quad (9),$$

30 where $f_{\text{soil_Holocene}}$, $f_{\text{soil_ICD}}$, and f_{plankton} are the fractions of Holocene soil, Ice Complex deposits,
 31 and riverine plankton contributing to each POM sample. The end-member values chosen for
 32 Holocene soil OM were $\delta^{13}\text{C} -26.6 \pm 1\text{‰}$ and $\Delta^{14}\text{C}$ of $-282 \pm 133\text{‰}$. As the two soil end-

1 members have very similar $\delta^{13}\text{C}$ values (see Table 4, Holocene soil $\delta^{13}\text{C} = -26.6 \pm 1\%$, Ice
2 Complex $\delta^{13}\text{C} = -26.3 \pm 0.67\%$), the $\delta^{13}\text{C}$ mainly determines the phytoplankton vs. total
3 (Holocene + Pleistocene) soil fraction, whereas $\Delta^{14}\text{C}$ mainly determines the fraction of
4 Holocene to Pleistocene soil. Therefore, the results concerning the total soil fraction are very
5 similar to those derived from the two-end-member model ($R^2=0.92$, mean two end-member
6 soil fraction is 0.43, mean three end-member is 0.46, Fig. S4) than derived with the two end-
7 member model.

8 As shown in Table S5 and Figure 4, the POM source determinations resulted in relative
9 fractions of 0.19-0.83, 0.11-0.65, and 0.07-0.34 for plankton, Holocene soil, and Ice Complex
10 deposits, respectively. Again, sample 31 taken off Kurungnakh Island (Ice Complex) stands
11 out with the highest contribution from ICD (fraction of 0.34) and sample 19 taken outside the
12 delta with highest contribution of phytoplankton (fraction of 0.83). Overall, with the end-
13 members chosen here and despite the high spatial variability within the delta, the riverine
14 phytoplankton fraction contributes most (mean of 0.55) to the surface water POM compared
15 to the Holocene soil OM (0.32) and Ice Complex deposits (0.14). The rather low OM
16 contribution from Ice Complex deposits reflects the distribution of these deposits in the Lena
17 watershed, where they are only locally concentrated within elevations up 400m (Grosse et al.,
18 2013).

19 **4.4 Implications of estimated soil-derived POM $\Delta^{14}\text{C}$**

20 The two binary mixing models (scenario 1 & 2) discussed above allow an estimate of the soil
21 $\Delta^{14}\text{C}$ values based on a contribution of modern phytoplankton-derived OM. Both scenarios
22 show considerably ^{14}C -depleted soil-derived OM compared to the bulk $^{14}\text{C}_{\text{POM}}$ concentrations.
23 This implies that the bulk POM ^{14}C age of samples taken in surface water during the summer,
24 when the riverine primary production is high, likely underestimate the age of the soil-derived
25 OM transported by the Lena River. The estimated soil $\Delta^{14}\text{C}$ values and ^{14}C ages in both
26 scenarios give a more plausible picture for soil-derived POM in the Lena River watershed. In
27 contrast to DOM that is restricted in its flow path to the unfrozen soil layers, POM is not
28 exclusively derived from surface soils. It also originates from resuspension of accumulated
29 pre-aged material along the river channels and from riverbank erosion. The latter contributes
30 POM with ^{14}C concentrations representing the whole range covered by the respective
31 riverbank bluffs. In the Lena Delta this is predominantly OM of late Holocene age with local
32 inputs from ice complex deposits of Pleistocene age (e.g. Bolshiyarov et al., 2015;
33 Schirrmeister et al., 2011; Schwamborn et al., 2002). About half of the POM in the Lena

1 Delta originates from the boreal forest hinterland south of the delta (Winterfeld et al. 2015,
2 companion paper). In the hinterland the soils along the Lena River and its tributaries can be
3 older than the delta soils, i.e. covering the whole age range from Holocene soils to Pleistocene
4 Ice Complex deposits (e.g. Grosse et al., 2013; Kuptsov and Lisitsin, 1996). Our estimated
5 soil ^{14}C ages of about 2,370 to 23,100 years (Table 5) for both scenarios therefore better
6 reflect these hinterland deposits contributing a heterogeneous ^{14}C age mix to riverine POM
7 than the bulk POM ^{14}C ages.

8 The soil POM ^{14}C estimates as well as the Lena Delta first terrace soil data ($\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$)
9 presented here improve our knowledge of the stable and radiocarbon isotopic range
10 characteristic for soil-derived OM exported by the Lena River to the Laptev Sea. This
11 information is critical for modeling the OM contribution from different terrestrial (fluvial vs.
12 coastal erosion) and marine sources to Laptev Sea sediments and thus help characterizing and
13 quantifying the OM pools released from permafrost thawing. Recent studies suggest that OM
14 exported by arctic rivers and OM derived from erosion of ice complex coasts differ in their
15 mineral and OM composition and thus show different potential for remineralization by
16 microorganisms after thawing as well as different modes of transport and burial (e.g. Feng et
17 al., 2013; Gustafsson et al., 2011; Knoblauch et al., 2013; Vonk et al., 2012). This has a direct
18 impact on how to assess the possibility of a positive carbon-climate feedback from permafrost
19 degradation, which has the potential to enhance global greenhouse warming by releasing huge
20 amounts of previously frozen OM to the atmosphere.

21 A promising approach to distinguish OM sequestered in arctic sediments is the dual-carbon-
22 isotope end-member simulation applied by Karlsson et al. (2011) and Vonk et al. (2012;
23 2010) to Laptev and East Siberian Sea sediments. The authors use the $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ values of
24 surface water suspended matter and surface sediments to quantify OM derived from
25 Pleistocene ice complex deposits, soil/top-soil OM exported by Siberian rivers, and marine
26 phytoplankton OM. Their end-member definitions for ice complex deposits and marine
27 primary production are rather well constrained. In contrast, the soil/topsoil end-member is
28 more difficult to define, particularly when using indirect parameters such as riverine DOM
29 and POM. Here the $\delta^{13}\text{C}$ end-member chosen for surface soil including our first terrace soil
30 data (Table S2) and our estimates for soil-derived POM (Table 5) provide new $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$
31 value ranges (Fig. 3B) for fluvially exported soil POM. Together with published $\delta^{13}\text{C}$ values
32 from tundra and taiga soils in Siberia and Alaska (Bird et al., 2002; Pitkänen et al., 2002; Xu
33 et al., 2009) we defined a Lena River soil OM end-member with a $\delta^{13}\text{C}$ value of $-26.6 \pm 1\%$.
34 Based on the $\delta^{13}\text{C}$ binary mixing model (scenario 2) the corresponding $\Delta^{14}\text{C}$ value is $-495 \pm$

1 153 ‰ (Table 5). We favor scenario 2 over the POC:PN-based scenario, because it allows to
2 calculate the soil fraction of each POM sample based on its bulk $\delta^{13}\text{C}$ value, which is a
3 mixture of soil and phytoplankton OM. In contrast, in the POC:PN-based scenario a constant
4 value for particulate inorganic nitrogen is subtracted, which does not necessarily represent the
5 actual inorganic nitrogen content of the particular sample. Moreover, it does not account for
6 selective degradation of labile carbon, which could result in overestimating the phytoplankton
7 contribution.

8 The above proposed $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ values for the soil OM end-member of the Lena River
9 catchment make it more complicated to distinguish between soil/top-soil derived OM from
10 the river and ice complex deposits from coastal erosion (see Fig. 3B). The $\delta^{13}\text{C}$ values of both
11 end-members are almost indistinguishable. The $\Delta^{14}\text{C}$ range of our soil-derived POM estimates
12 is lower than the end-members used by Karlsson et al. (2011) and Vonk et al. (2012, 2010).
13 Furthermore, Höfle et al. (2013) have shown that OM within the first 30cm of a polygon rim
14 of the Lena Delta first terrace can be 3,000 ^{14}C years old, which make the end-members
15 chosen for fluvial exported soil/top-soil OM by Karlsson et al. (2011) and Vonk et al. (2012;
16 2010) appear too young. Using the bulk surface water POM and DOM $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ values
17 as end-member could therefore highly over- or underestimate the soil OM contribution from
18 permafrost watersheds and in turn highly over- or underestimate OM contribution from ice
19 complex to marine sediments.

20 However, we are aware of the limitations and uncertainties associated with the soil $\Delta^{14}\text{C}$
21 estimates discussed above (and in sections 4.3.1, 4.3.2). Without determining the
22 phytoplankton biomass of each sample by microscopic counting or from chlorophyll-*a*
23 analysis, the plankton OM fraction calculated based on POC:PN ratios (section 4.3.1) and
24 based $\delta^{13}\text{C}$ values (section 4.3.2) can only be regarded as rough estimates. These estimates
25 give orders of magnitude of OM contribution from the individual sources rather than exact
26 values, which in turn provide a possible range of $\Delta^{14}\text{C}$ values for soil-derived POM. An
27 additional source of uncertainty is our assumption of a modern ^{14}C concentration of plankton
28 OM. Without determining the ^{14}C concentration of the Lena River DIC, which is utilized by
29 phytoplankton, we cannot be sure of a modern ^{14}C concentration. Lena River DIC is derived
30 from several sources providing carbon with different ^{14}C concentrations. DIC derived from
31 carbonate and silicate weathering is ^{14}C -depleted, DIC derived from soil respiration has a
32 broad range of $\Delta^{14}\text{C}$ values due decomposition of soil OM pools of varying age, and DIC
33 derived from exchange with the atmosphere has modern $\Delta^{14}\text{C}$ values. The resulting DIC $\Delta^{14}\text{C}$
34 value is mixture of these sources depending on the varying contribution from each source.

1 Furthermore, Tank et al. (2012) found that DIC yields are negatively correlated with
2 continuous permafrost extent in the watersheds of the six large Arctic rivers including the
3 Lena. This would imply that carbonate weathering is to some extent hampered by continuous
4 permafrost making up 77% of the Lena catchment area (Tank et al., 2012). In summary,
5 because there is no DIC $\Delta^{14}\text{C}$ value available for the Lena River and there are too many
6 factors influencing the DIC $\Delta^{14}\text{C}$ value, we made the simplified assumption of modern $\Delta^{14}\text{C}$
7 of 41.9 ± 4.2 (average value of atmospheric CO_2 $\Delta^{14}\text{C}$ May-Aug 2009-2011 from Levin et al.,
8 2013). Consequently, if true $\Delta^{14}\text{C}$ values of DIC in the Lena were depleted relative to the
9 modern atmosphere, the soil-derived POM would be less ^{14}C depleted than estimated here.
10 Thus, $\Delta^{14}\text{C}$ values for soils have to be considered minimum estimates or in other words, the
11 estimated ^{14}C soil ages have to be considered maximum ages.

12 The best way to determine the $\Delta^{14}\text{C}$ value of riverine soil-derived OM would be a biomarker-
13 specific radiocarbon analysis using source-specific compounds, e.g., short- and long-chain
14 alkanolic acids for plankton- and terrestrial-derived OM, respectively. However, for these
15 analyses large samples of POM are needed. The samples analyzed during our study were too
16 small to allow for compound-specific dating.

17

18 **5 Conclusions**

19 There are only few data available on ^{14}C concentrations of POM from Lena River surface
20 water, but regarding the likely positive carbon-climate feedback to greenhouse warming the
21 quality and fate of this permafrost OM pool in the coastal waters of the Laptev Sea is
22 currently under debate (e.g. Feng et al., 2013; Gustafsson et al., 2011; Karlsson et al., 2011;
23 Vonk et al., 2012). With this study we provide one of the first data sets on surface water POM
24 ^{14}C concentrations from the Lena Delta sampled during the summers 2009 and 2010 and
25 during spring 2011 (n=30 samples). The contribution of modern phytoplankton POM to these
26 samples was on the one hand estimated using binary mixing models based on POC:PN ratios
27 and $\delta^{13}\text{C}$ values, which allowed us to calculate the $\Delta^{14}\text{C}$ values of the soil-derived POM
28 fraction. These soil $\Delta^{14}\text{C}$ estimates were low compared to the bulk POM $\Delta^{14}\text{C}$ values and
29 therefore seem to represent the heterogeneous ^{14}C mix of soil OM ranging from Holocene to
30 Pleistocene age (e.g. ice complex deposits) in the Lena River watershed more accurately.
31 Moreover, we applied a dual carbon-isotope three end-member model to further distinguish
32 between OM contributions from Holocene soils and Pleistocene Ice Complex deposits to the
33 soil fraction. Here, we could show that the overall contribution of Ice Complex deposits to

1 surface water POM in the Lena Delta was relatively low, which reflects the restricted spatial
2 distribution of these deposits within the Lena watershed. Only samples taken close to Ice
3 Complex deposits exhibited higher contributions of this source in the model implying a small,
4 locally pronounced influence on surface water POM before it becomes mixed with other soil-
5 derived POM during fluvial transport.

6 Because of the limitations of our approach, particularly the assumption of modern
7 phytoplankton OM without determining the ^{14}C concentration of the Lena River DIC utilized
8 by phytoplankton, our ^{14}C estimates for the soil-derived fraction have to be considered
9 minimum $\Delta^{14}\text{C}$ concentrations and maximum ^{14}C ages, respectively. Nonetheless, we propose
10 average values for the soil POM isotopic composition based on our data and published values
11 of $\delta^{13}\text{C} = -26.6 \pm 1 \text{ ‰}$ and $\Delta^{14}\text{C} = -495 \pm 153 \text{ ‰}$ (Tables 5 and S2), which will be useful for
12 dual-carbon-isotope simulations focusing on unraveling the OM contributed by different
13 terrigenous (fluvial vs. coastal erosion) and marine sources to arctic sediments.

14

15 The complete data set presented here can also be found in PANGAEA (www.pangaea.de).

16

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30

1 **References**

- 2 Ahad, J. M. E., Barth, J. A. C., Ganeshram, R. S., Spencer, R. G. M., and Uher, G.: Controls
3 on carbon cycling in two contrasting temperate zone estuaries: The Tyne and Tweed, UK,
4 *Estuar. Coast. Shelf Sci.*, 78, 685–693, doi:10.1016/j.ecss.2008.02.006, 2008.
- 5 Alling, V., Porcelli, D., Mörrh, C. M., Anderson, L. G., Sanchez-Garcia, L., Gustafsson, Ö.,
6 Andersson, P. S., and Humborg, C.: Degradation of terrestrial organic carbon, primary
7 production and out-gassing of CO₂, *Geochim. Cosmochim. Ac.*, 95, 143–159,
8 doi:10.1016/j.gca.2012.07.028, 2012.
- 9 Amon, R. M. W., Rinehart, A. J., Duan, S., Louchouart, P., Prokushkin, A., Guggenberger,
10 G., Bauch, D., Stedmon, C., Raymond, P. A., Holmes, R. M., McClelland, J. W., Peterson, B.
11 J., Walker, S. A., and Zhulidov, A. V.: Dissolved organic matter sources in large Arctic
12 rivers, *Geochim. Cosmochim. Ac.*, 94, 217–237, doi:10.1016/j.gca.2012.07.015, 2012.
- 13 ACIA: Impacts of a warming Arctic–Arctic Climate Impact Assessment, Cambridge,
14 Cambridge University Press, pp. 146, 2004.
- 15 Bird, M. I., Santruckova, H., Arneeth, A., Grigoriev, S., Gleixner, G., Kalaschnikov, Y. N.,
16 Lloyd, J., and Schulze, E. D.: Soil carbon inventories and carbon-13 on a latitude transect in
17 Siberia, *Tellus B*, 54, 631–641, doi:10.1034/j.1600-0889.2002.01334.x, 2002.
- 18 Boike, J., Kattenstroth, B., Abramova, K., Bornemann, N., Chetverova, A., Fedorova, I.,
19 Fröb, K., Grigoriev, M., Grüber, M., Kutzbach, L., Langer, M., Minke, M., Muster, S., Piel,
20 K., Pfeiffer, E.-M., Stoof, G., Westermann, S., Wischnewski, K., Wille, C., and Hubberten, H.
21 W.: Baseline characteristics of climate, permafrost and land cover from a new permafrost
22 observatory in the Lena River Delta, Siberia (1998-2011), *Biogeosciences*, 10 (3), 2105–
23 2128, doi:10.5194/bg-10-2105-2013, 2013.
- 24 Bolshiyarov, D., Makarov, A., and Savelieva, L.: Lena River delta formation during the
25 Holocene, *Biogeosciences*, 12, 579–593, doi:10.5194/bg-12-579-2015, 2015.
- 26 Cauwet, G. and Sidorov, I.: The biogeochemistry of Lena River: organic carbon and nutrients
27 distribution, *Mar. Chem.*, 53, 211–227, 1996.
- 28 Chanton, J. and Lewis, F. G.: Examination of coupling between primary and secondary
29 production in a river-dominated estuary: Apalachicola Bay, Florida, USA, *Limnol. Oceanogr.*,
30 47(3), 683–697, 2002.
- 31 Charkin, A., Dudarev, O., Semiletov, I., Kruhmalev, A., Vonk, J., Sanchéz-García, L.,

1 Karlsson, E., and Gustafsson, Ö.: Seasonal and interannual variability of sedimentation and
2 organic matter distribution in the Buor-Khaya Gulf: the primary recipient of input from Lena
3 River and coastal erosion in the southeast Laptev Sea, *Biogeosciences*, 8(9), 2581–2594,
4 doi:10.5194/bg-8-2581-2011, 2011.

5 Dickens, A. F., Baldock, J., Kenna, T. C., and Eglinton, T. I.: A depositional history of
6 particulate organic carbon in a floodplain lake from the lower Ob' River, Siberia, *Geochim.
7 Cosmochim. Ac.*, 75(17), 4796–4815, doi:10.1016/j.gca.2011.05.032, 2011.

8 Feng, X., Vonk, J. E., van Dongen, B. E., Gustafsson, Ö., Semiletov, I. P., Dudarev, O. V.,
9 Wang, Z., Montluçon, D. B., Wacker, L., and Eglinton, T. I.: Differential mobilization of
10 terrestrial carbon pools in Eurasian Arctic river basins, *P. Natl. Acad. Sci. USA*, 110 (35),
11 14168–14173, doi:10.1073/pnas.1307031110/-DCSupplemental/pnas.201307031SI.pdf,
12 2013.

13 Galimov, E. M., Kodina, L. A., Stepanets, O. V., and Korobeinik, G. S.: Biogeochemistry of
14 the Russian Arctic. Kara Sea: Research results under the SIRRO project, 1995–2003,
15 *Geochem. Int.*, 44(11), 1053–1104, doi:10.1134/S0016702906110012, 2006.

16 Goñi, M., Teixeira, M., and Perkey, D.: Sources and distribution of organic matter in a river-
17 dominated estuary (Winyah Bay, SC, USA), *Estuar. Coast. Shelf Sci.*, 57 (5-6), 1023–1048,
18 doi:10.1016/S0272-7714(03)00008-8, 2003.

19 Goñi, M., Yunker, M., Macdonald, R., and Eglinton, T.: Distribution and sources of organic
20 biomarkers in arctic sediments from the Mackenzie River and Beaufort Shelf, *Mar. Chem.*,
21 71, 23–51, 2000.

22 Goñi, M., Yunker, M., Macdonald, R., and Eglinton, T.: The supply and preservation of
23 ancient and modern components of organic carbon in the Canadian Beaufort Shelf of the
24 Arctic Ocean, *Mar. Chem.*, 93 (1), 53–73, doi:10.1016/j.marchem.2004.08.001, 2005.

25 Gordeev, V. and Sidorov, I.: Concentrations of Major Elements and Their Outflow Into the
26 Laptev Sea by the Lena River, *Marine Geochem.*, 43, 33–45. 1993.

27 Grigoriev, M.: Cryomorphogenesis in the Lena Delta, Permafrost Institute Press, 1993.

28 Grosse, G., Robinson, J. E., Bryant, R., Taylor, M. D., Harper, W., DeMasi, A., Kyker-
29 Snowman, E., Veremeeva, A., Schirrmeyer, L., and Harden, J.: Distribution of late
30 Pleistocene ice-rich syngenetic permafrost of the Yedoma Suite in east and central Siberia,
31 Russia, US Geological Survey Open File Report 2013-1078, 37p, 2013.

1 Guo, L. and Macdonald, R. W.: Source and transport of terrigenous organic matter in the
2 upper Yukon River: Evidence from isotope ($\delta^{13}\text{C}$, $\Delta^{14}\text{C}$, and $\delta^{15}\text{N}$) composition of
3 dissolved, colloidal, and particulate phases, *Global Biogeochem. Cy.*, 20, GB2011,
4 doi:10.1029/2005GB002593, 2006.

5 Guo, L., Semiletov, I., Gustafsson, Ö., Ingri, J., Andersson, P., Dudarev, O., and White, D.:
6 Characterization of Siberian Arctic coastal sediments: Implications for terrestrial organic
7 carbon export, *Global Biogeochem. Cy.*, 18, GB1036, doi:10.1029/2003GB002087, 2004.

8 Guo, L., Ping, C., and Macdonald, R. W.: Mobilization pathways of organic carbon from
9 permafrost to arctic rivers in a changing climate, *Geophys. Res. Lett.*, 34, L13603,
10 doi:10.1029/2007GL030689, 2007.

11 Gustafsson, Ö., van Dongen, B., Vonk, J., Dudarev, O., and Semiletov, I.: Widespread release
12 of old carbon across the Siberian Arctic echoed by its large rivers, *Biogeosciences*, 8, 1737–
13 1743, doi:10.5194/bg-8-1737-2011, 2011.

14 Günther, F., Overduin, P., Sandakov, A. V., Grosse, G., and Grigoriev, M.: Short- and long-
15 term thermo-erosion of ice-rich permafrost coasts in the Laptev Sea region, *Biogeosciences*,
16 10, 4297–4318, doi:10.5194/bg-10-4297-2013, 2013.

17 Hedges, J. and Oades, J.: Comparative organic geochemistries of soils and marine sediments,
18 *Org. Geochem.*, 27, 319–361, 1997.

19 Hedges, J., Keil, R., and Benner, R.: What happens to terrestrial organic matter in the ocean?
20 *Organic Geochemistry*, 27, 195–212, 1997.

21 Holmes, R., McClelland, J., Peterson, B., Shiklomanov, I., Shiklomanov, A., Zhulidov, A.,
22 Gordeev, V., and Bobrovitskaya, N.: A circumpolar perspective on fluvial sediment flux to
23 the Arctic Ocean, *Global Biogeochem. Cy.*, 16, 1098, doi:10.1029/2001GB001849, 2002.

24 Holmes, R., McClelland, J., Peterson, B., Tank, S., Bulygina, E., Eglinton, T., Gordeev, V.,
25 Gurtovaya, T., Raymond, P., Repeta, D., Staples, R., Striegl, R., Zhulidov, A., and Zimov, S.:
26 Seasonal and Annual Fluxes of Nutrients and Organic Matter from Large Rivers to the Arctic
27 Ocean and Surrounding Seas, *Estuar. Coast.*, 35, 369–382, doi:10.1007/s12237-011-9386-6,
28 2012.

29 Höfle, S., Rethemeyer, J., Mueller, C. W., and John, S.: Organic matter composition and
30 stabilization in a polygonal tundra soil of the Lena Delta, *Biogeosciences*, 10, 3145–3158,
31 doi:10.5194/bg-10-3145-2013, 2013.

- 1 IPCC: Climate change 2013. The physical science basis: Working group I contribution to the
2 fifth assessment report of the IPCC, edited by Stocker, T.F., Qin, D., Plattner, G.-K., Tignor,
3 M.M.B., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., and Midgley, P.M., IPCC, 5,
4 pp. 1525, Cambridge University Press, Cambridge, UK and New York, USA, 2013.
- 5 Ivanov, V. V. and Piskun, A. A.: Distribution of river water and suspended sediment loads in
6 the deltas of rivers in the basins of the Laptev and East-Siberian Seas, in: Land-ocean system
7 in the Siberian Arctic. Dynamics and history, edited by: Kassens, H., Bauch, H. A.,
8 Dmitrenko, I. A., Eicken, H., Hubberten, H.-W., Melles, M., Thiede, J., and Timokhov, L. A.,
9 239–250, Springer Berlin, Germany. 1999.
- 10 Karlsson, E., Charkin, A., Dudarev, O., Semiletov, I., Vonk, J., Sánchez-García, L.,
11 Andersson, A., and Gustafsson, Ö.: Carbon isotopes and lipid biomarker investigation of
12 sources, transport and degradation of terrestrial organic matter in the Buor-Khaya Bay, SE
13 Laptev Sea, *Biogeosciences*, 8, 1865–1879, doi:10.5194/bg-8-1865-2011, 2011.
- 14 Knoblauch, C., Beer, C., Sosnin, A., Wagner, D., and Pfeiffer, E.-M.: Predicting long-term
15 carbon mineralization and trace gas production from thawing permafrost of Northeast Siberia,
16 *Glob. Change Biol.*, 19, 1160–1172, doi:10.1111/gcb.12116, 2013.
- 17 Kraberg, A. C., Druzhkova, E., Heim, B., Loeder, M. J. G., and Wiltshire, K. H.:
18 Phytoplankton community structure in the Lena Delta (Siberia, Russia) in relation to
19 hydrography, *Biogeosciences*, 10, 7263–7277, doi:10.5194/bg-10-7263-2013, 2013.
- 20 Kuhry, P. and Vitt, D.: Fossil carbon/nitrogen ratios as a measure of peat decomposition,
21 *Ecology*, 77, 271–275, 1996.
- 22 Kuptsov, V. and Lisitsin, A.: Radiocarbon of quaternary along shore and bottom deposits of
23 the Lena and the Laptev Sea sediments, *Mar. Chem.*, 53, 301–311. 1996.
- 24 Kusch, S., Rethemeyer, J., Schefuß, E., and Mollenhauer, G.: Controls on the age of vascular
25 plant biomarkers in Black Sea sediments, *Geochim. Cosmochim. Ac.*, 74, 7031–7047, 2010.
- 26 Kutzbach, L., Wagner, D., and Pfeiffer, E.: Effect of microrelief and vegetation methane
27 emission from polygonal wet tundra, Lena Delta, Northern Siberia, *Biogeochemistry*, 69, 341-
28 362, 2004.
- 29 Levin, I., Kromer, B., and Hammer, S.: Atmospheric $\Delta^{14}\text{CO}_2$ end in Western European
30 background air from 2000-2012, *Tellus B*, 65, 20092, 2013.
- 31 Lisitsyn, A. P.: The marginal filter of the ocean, *Oceanol. Russ. Acad. Sci.*, 34, 671–682,

1 1995.

2 Lobbes, J., Fitznar, H., and Kattner, G.: Biogeochemical characteristics of dissolved and
3 particulate organic matter in Russian rivers entering the Arctic Ocean, *Geochim. Cosmochim.*
4 *Ac.*, 64, 2973–2983, 2000.

5 Markus, T., Stroeve, J. C., and Miller, J.: Recent changes in Arctic sea ice melt onset,
6 freezeup, and melt season length, *J. Geophys. Res.*, 114, C12024,
7 doi:10.1029/2009JC005436, 2009.

8 McClelland, J. W., Holmes, R., Dunton, K., and Macdonald, R.: The Arctic Ocean estuary,
9 *Estuaries and Coasts*, 35, 353–368, 2012.

10 McGuire, A., Anderson, L., Christensen, T., Dallimore, S., Guo, L., Hayes, D., Heimann, M.,
11 Lorenson, T., Macdonald, R., and Roulet, N.: Sensitivity of the carbon cycle in the Arctic to
12 climate change, in *Ecol. Monogr.*, 79, 523–555, Ecological Society of America. 2009.

13 McNichol, A. P., Osborne, E. A., Gagnon, A. R., Fry, B., and Jones, G. A.: TIC, TOC, DIC,
14 DOC, PIC, POC—unique aspects in the preparation of oceanographic samples for 14C-AMS,
15 *Nucl. Instr. Methods Phys. R. B*, 92, 162–165, doi:10.1016/0168-583X(94)95998-6, 1994.

16 Meyers, P. A.: Preservation of Elemental and Isotopic Source Identification of Sedimentary
17 Organic-Matter, *Chem. Geol.*, 114, 289–302, doi:10.1016/0009-2541(94)90059-0, 1994.

18 Meyers, P. A. and Lallier-vergés, E.: Lacustrine sedimentary organic matter records of Late
19 Quaternary paleoclimates, *J. Paleolimnol.*, 21, 345–372, doi:10.1023/A:1008073732192,
20 1999.

21 Mook, W. G. and Tan, F. C.: Stable carbon isotopes in rivers and estuaries, in: SCOPE Report
22 42, *Biogeochemistry of major world rivers*, edited by: Degens, E. T., Kempe, S. and Richey,
23 J., 245–264, Wiley & Sons, New York, 1991.

24 Morgenstern, A., Grosse, G., and Schirrmeister, L.: Genetic, morphological, and statistical
25 characterization of lakes in the permafrost-dominated Lena Delta, in: *Proceedings of the*
26 *Ninth International Conference on Permafrost*, 1239–44, 2008.

27 Mueller-Lupp, T., Bauch, H., Erlenkeuser, H., Hefter, J., Kassens, H., and Thiede, J.: Changes
28 in the deposition of terrestrial organic matter on the Laptev Sea shelf during the Holocene:
29 evidence from stable carbon isotopes, *Int. J. Earth Sci.*, 89, 563–568,
30 doi:10.1007/s005310000128, 2000.

31 Neff, J., Finlay, J., Zimov, S., Davydov, S., Carrasco, J., Sschoor, E., and Davydova, A.:

1 Seasonal changes in the age and structure of dissolved organic carbon in Siberian rivers and
2 streams, *Geophys. Res. Lett.*, 33, L23401, doi:10.1029/2006GL028222, 2006.

3 Oades, J. M.: The retention of organic matter in soils, *Biogeochemistry*, 5, 35–70,
4 doi:10.1007/BF02180317, 1988.

5 Peterson, B., Holmes, R., McClelland, J., Vörösmarty, C., Lammers, R., Shiklomanov, A.,
6 Shiklomanov, I., and Rahmstorf, S.: Increasing river discharge to the Arctic Ocean, *Science*,
7 298, 2171–2173, 2002.

8 Pitkänen, A., Turunen, J., Tahvanainen, T., and Tolonen, K.: Holocene vegetation history
9 from the Salym-Yugan Mire Area, West Siberia, *The Holocene*, 12, 353–362,
10 doi:10.1191/0959683602hl533rp, 2002.

11 Rachold, V. and Hubberten, H.-W.: Carbon isotope composition of particulate organic
12 material in East Siberian rivers, in: *Land-ocean system in the Siberian Arctic. Dynamics and*
13 *history*, edited by: Kassens, H., Bauch, H. A., Dmitrenko, I. A., Eicken, H., Hubberten, H.-
14 W., Melles, M., Thiede, J., and Timokhov, L. A., 223–238, Springer Berlin, Germany. 1999.

15 Rachold, V., Eicken, H., Gordeev, V. V., Grigoriev, M. N., Hubberten, H. W., Lisitzin, A. P.,
16 Shevchenko, V. P., and Schirrmeister, L.: Modern terrigenous organic carbon input to the
17 Arctic Ocean, in: *The organic carbon cycle in the Arctic Ocean*, edited by: Stein R. and
18 Macdonald, R. W., 33–55. 2004.

19 Raymond, P. and Bauer, J.: Use of ¹⁴C and ¹³C natural abundances for evaluating riverine,
20 estuarine, and coastal DOC and POC sources and cycling: a review and synthesis, *Org.*
21 *Geochem.*, 32, 469–485, 2001.

22 Raymond, P., McClelland, J., Holmes, R., Zhulidov, A., Mull, K., Peterson, B., Striegl, R.,
23 Aiken, G., and Gurtovaya, T.: Flux and age of dissolved organic carbon exported to the Arctic
24 Ocean: A carbon isotopic study of the five largest arctic rivers, *Glob. Biogeochem. Cy.*, 21,
25 GB4011, doi:10.1029/2007GB002934, 2007.

26 Sánchez-García, L., Alling, V., Pugach, S., Vonk, J., van Dongen, B., Humborg, C., Dudarev,
27 O., Semiletov, I., and Gustafsson, Ö.: Inventories and behavior of particulate organic carbon
28 in the Laptev and East Siberian seas, *Glob. Biogeochem. Cy.*, 25, GB2007,
29 doi:10.1029/2010GB003862, 2011.

30 Sanders, T.: Charakterisierung Ammoniak oxidierender Mikroorganismen in Böden kalter
31 gemäßigtter Klimate und ihre Bedeutung für den globalen Stickstoffkreislauf, PhD Thesis,
32 University of Hamburg, Hamburg, 2011.

1 Schirrmeister, L., Grosse, G., Wetterich, S., Overduin, P., Strauss, J., Schuur, E. A. G., and
2 Hubberten, H. W.: Fossil organic matter characteristics in permafrost deposits of the northeast
3 Siberian Arctic, *J. Geophys. Res.*, 116, G00M02, doi:10.1029/2011JG001647, 2011.

4 Schubert, C. J. and Calvert, S. E.: Nitrogen and carbon isotopic composition of marine and
5 terrestrial organic matter in Arctic Ocean sediments:, *Deep-Sea Res. Pt. I: Oceanographic*
6 *Research Papers*, 48, 789–810, doi:10.1016/S0967-0637(00)00069-8, 2001.

7 Schuur, E., Bockheim, J., Canadell, J., Euskirchen, E., Field, C., Goryachkin, S., Hagemann,
8 S., Kuhry, P., Lafleur, P., Lee, H., Mazhitova, G., Nelson, F., Rinke, A., Romanovsky, V.,
9 Shiklomanov, N., Tarnocai, C., Venevsky, S., Vogel, J., and Zimov, S.: Vulnerability of
10 permafrost carbon to climate change: Implications for the global carbon cycle, *Bioscience*, 58,
11 701–714, doi:10.1641/B580807, 2008.

12 Schuur, E., Vogel, J., Crummer, K., Lee, H., Sickman, J., and Osterkamp, T.: The effect of
13 permafrost thaw on old carbon release and net carbon exchange from tundra, *Nature*, 459,
14 556–559, doi:10.1038/nature08031, 2009.

15 Schwamborn, G., Rachold, V., and Grigoriev, M.: Late Quaternary sedimentation history of
16 the Lena Delta, *Quatern. Int.*, 89, 119–134, 2002.

17 Semiletov, I., Pipko, I., Shakhova, N., Dudarev, O., Pugach, S., Charkin, A., McRoy, C.,
18 Kosmach, D., and Gustafsson, Ö.: Carbon transport by the Lena River from its headwaters to
19 the Arctic Ocean, with emphasis on fluvial input of terrestrial particulate organic carbon vs.
20 carbon transport by coastal erosion, *Biogeosciences*, 8, 2407–2426, doi:10.5194/bg-8-2407-
21 2011, 2011.

22 Serreze, M. C., Walsh, J. E., Chapin, F. S., III, Osterkamp, T., Dyrgerov, M., Romanovsky,
23 V., Oechel, W. C., Morison, J., Zhang, T., and Barry, R. G.: Observational Evidence of
24 Recent Change in the Northern High-Latitude Environment, *Climatic Change*, 46, 159–207,
25 doi:10.1023/A:1005504031923, 2000.

26 Sorokin, Y. I. and Sorokin, P. Y.: Plankton and primary production in the Lena River estuary
27 and in the south-eastern Laptev Sea, *Estuar. Coast. Shelf Sci.*, 43, 399–418, 1996.

28 Stuiver, M. and Polach, H.: Discussion. Reporting of ^{14}C data, *Radiocarbon*, 19, 355–363,
29 1977.

30 Tank, S. E., Raymond, P. A., Striegl, R. G., McClelland, J. W., Holmes, R. M., Fiske, G. J.,
31 and Peterson, G. J.: A land-to-ocean perspective on the magnitude, source, and implication of
32 DIC flux from major Arctic rivers to the Arctic Ocean, *Glob. Biogeochem.Cy.*, 26, GB4018,

1 doi:10.1029/2011GB004192, 2012.

2 Tarnocai, C., Canadell, J., Schuur, E., Kuhry, P., Mazhitova, G., and Zimov, S.: Soil organic
3 carbon pools in the northern circumpolar permafrost region, *Glob. Biochem. Cy.*, 23,
4 GB2023, doi:10.1029/2008GB003327, 2009.

5 Trumbore, S.: Radiocarbon and Soil Carbon Dynamics, *Annu. Rev. Earth Planet. Sci.*, 37,
6 47–66, doi:10.1146/annurev.earth.36.031207.124300, 2009.

7 Trumbore, S. E.: Comparison of Carbon Dynamics in Tropical and Temperate Soils Using
8 Radiocarbon Measurements, *Glob. Biogeochem. Cy.*, 7, 275–290, doi:10.1029/93GB00468,
9 1993.

10 van Dongen, B. E., Zencak, Z., and Gustafsson, Ö.: Differential transport and degradation of
11 bulk organic carbon and specific terrestrial biomarkers in the surface waters of a sub-arctic
12 brackish bay mixing zone, *Mar. Chem.*, 112, 203–214, doi:10.1016/j.marchem.2008.08.002,
13 2008.

14 Vonk, J. and Gustafsson, Ö.: Calibrating n-alkane Sphagnum proxies in sub-Arctic
15 Scandinavia, *Org. Geochem.*, 40, 1085–1090, doi:10.1016/j.orggeochem.2009.07.002, 2009.

16 Vonk, J. E., Sánchez-García, L., van Dongen, B. E., Alling, V., Kosmach, D., Charkin, A.,
17 Semiletov, I. P., Dudarev, O. V., Shakhova, N., Roos, P., Eglinton, T. I., Andersson, A., and
18 Gustafsson, Ö.: Activation of old carbon by erosion of coastal and subsea permafrost in Arctic
19 Siberia, *Nature*, 489, 137–140, doi:10.1038/nature11392, 2012.

20 Vonk, J., Sánchez-García, L., Semiletov, I., Dudarev, O., Eglinton, T., Andersson, A., and
21 Gustafsson, Ö.: Molecular and radiocarbon constraints on sources and degradation of
22 terrestrial organic carbon along the Kolyma paleoriver transect, East Siberian Sea,
23 *Biogeosciences*, 7, 3153–3166, doi:10.5194/bg-7-3153-2010, 2010.

24 Wetterich, S., Kuzmina, S., Andreev, A., Kienast, F., Meyer, H., Schirrmeister, L.,
25 Kuznetsova, T., and Sierralta, M.: Palaeoenvironmental dynamics inferred from late
26 Quaternary permafrost deposits on Kurungnakh Island, Lena Delta, Northeast Siberia, Russia,
27 *Quaternary Sci. Rev.*, 27, 1523–1540, doi:10.1016/j.quascirev.2008.04.007, 2008.

28 Winterfeld, M., Goñi, M., Just, J., Hefter, J., and Mollenhauer, G.: Characterization of
29 particulate organic matter in the Lena River Delta and adjacent nearshore zone, NE Siberia.
30 Part II: Lignin-derived phenol composition, *Biogeosciences*, 12, 2261–2283, doi:10.5194/bg-
31 12-2261-015, 2015.

- 1 Xu, C., Guo, L., Ping, C., and White, D.: Chemical and isotopic characterization of size-
2 fractionated organic matter from cryoturbated tundra soils, northern Alaska, *J. Geophys. Res.*,
3 114, G03002, doi:10.1029/2008JG000846, 2009.
- 4 Zhang, T., Frauenfeld, O., Serreze, M., Etringer, A., Oelke, C., McCreight, J., Barry, R.,
5 Gilichinsky, D., Yang, D., Ye, H., Ling, F., and Chudinova, S.: Spatial and temporal
6 variability in active layer thickness over the Russian Arctic drainage basin, *J. Geophys. Res.*,
7 110, D16101, doi:10.1029/2004JD005642, 2005.
- 8 Zimov, N., Zimov, S., Zimova, A., Zimova, G., Chuprynin, V., and Chapin, F.: Carbon
9 storage in permafrost and soils of the mammoth tundra-steppe biome: Role in the global
10 carbon budget, *Geophys. Res. Lett.*, 36, L02502, doi:10.1029/2008GL036332, 2009.
- 11 Zimov, S., Schuur, E., and Chapin, F.: Permafrost and the global carbon budget, *Science*, 312,
12 1612–1613, doi:10.1126/science.1128908, 2006.
- 13 Zubrzycki, S.: Organic carbon pools in permafrost-affected soils of Siberian arctic regions,
14 Ph.D, University of Hamburg. 2013.
- 15 Zubrzycki, S., Kutzbach, L., and Pfeiffer, E.: Variability of soil organic carbon stocks of
16 different permafrost-affected soils: Initial results from a North-South transect in Siberia,
17 *Proceedings of the Tenth International Conference on Permafrost*, 485-490, 2012.
- 18 Zubrzycki, S., Kutzbach, L., Grosse, G., Desyatkin, A., and Pfeiffer, E.: Organic carbon and
19 total nitrogen stocks in soils of the Lena River Delta, *Biogeosciences*, 10, 3507-3524,
20 doi:10.5194/bg-10-3507-013, 2013a.
- 21 Zubrzycki, S.: Organic carbon pools in permafrost-affected soils of Siberian arctic regions,
22 Ph.D, University of Hamburg, 2013b.

1 Table 1. Soil samples from riverbank bluffs and total suspended matter (TSM) samples
 2 presented in this study analyzed for particulate organic carbon, stable, and radiocarbon
 3 isotope composition. Latitude and longitude are given in decimal degrees (dec). Bluff height
 4 is given in meters above river level [m a.r.l.] measured in August 2009 and only applicable
 5 for the soil samples. The TSM samples were taken from the surface water layer at a sampling
 6 depth of ca. 0.5m.

Sample code	Sample & site description	Date of sampling	Lat.N [dec]	Long. E [dec]	Bluff height [m a.r.l.]
<i>Lena Delta first terrace soil profiles</i>					
L09-12	Samoylov Island, 5 depths sampled	18-Aug-2009	72.3775	126.4954	7.5
L09-28-2	Bykovskaya Channel, 2 depths sampled	21-Aug-2009	72.0586	128.6309	1.7
<i>Lena Delta TSM</i>					
1	Olenyokskaya Channel	14-Aug-2009	72.4772	125.2856	
2	Olenyokskaya Channel	14-Aug-2009	72.3598	125.6728	
3	Lena River main channel	16-Aug-2009	72.1526	126.9160	
4	Lena River main channel south of Tit Ari Island	16-Aug-2009	71.9040	127.2544	
5	Sardakhskaya/Trofimovskaya Channel	17-Aug-2009	72.5825	127.1891	
6	Sardakhskaya Channel	17-Aug-2009	72.7002	127.4930	
7	Sardakhskaya/Trofimovskaya Channel	17-Aug-2009	72.6268	127.3860	
8	near Kurungnakh Island	18-Aug-2009	72.2904	126.0909	
9	Lena River main channel	19-Aug-2009	72.2987	126.7080	
10	Lena River main channel	19-Aug-2009	72.2760	126.9041	
11	Lena River main channel	19-Aug-2009	72.5159	126.7142	
12	Bykovskaya Channel	20-Aug-2009	72.4140	126.9124	
13	Lena River Bykovskaya Channel	20-Aug-2009	72.2352	127.9619	
14	Lena River Bykovskaya Channel	20-Aug-2009	72.0341	128.5232	
15	Lena River Bykovskaya Channel	21-Aug-2009	72.0354	128.0974	
16	Lena River Bykovskaya Channel	21-Aug-2009	72.0586	128.6309	
17	offshore Bykovsky Peninsula	22-Aug-2010	71.7889	129.4189	
18	NE of Muostakh Island	22-Aug-2010	71.6761	130.1728	
19	NE of Muostakh Island	22-Aug-2010	71.7062	130.2900	
20	W of Muostakh Island	23-Aug-2010	71.6088	129.9393	
21	close to Muostakh Island shoreline	23-Aug-2010	71.5750	129.8200	
22	close to Samoylov Island	30-Jul-2010	72.3650	126.4628	
24	Sardakhskaya/Trofimovskaya Channel	31-Jul-2010	72.5343	126.8794	
25	Lena River Trofimoskaya Channel	31-Jul-2010	72.4764	126.6250	
26	Lena River Trofimoskaya Channel	31-Jul-2010	72.4764	126.8588	
27	Lena River main channel south of Samoylov	1-Aug-2010	72.3776	126.7478	
28	Lena River main channel north of Tit Ari Island	1-Aug-2010	72.2102	126.9423	
29	Lena River main channel south of Tit Ari Island	1-Aug-2010	71.9514	127.2582	

30	Lena River main channel off Kurungnakh	2-Aug-2010	72.2808	126.2091
31	Lena River main channel	2-Aug-2010	72.3567	126.3521
32	Lena River Bykovskaya Channel	3-Aug-2010	72.3604	127.6761
33	Bykovskaya Channel	3-Aug-2010	72.3604	127.6765
34	off Bykovsky Peninsula	4-Aug-2010	71.7015	129.7523
35	offshore Lena Delta	6-Aug-2010	72.0379	129.7694
36	offshore Lena Delta	6-Aug-2010	72.2753	129.8248
37	Lena River main channel off Samoylov Island	29-May-2011	72.3651	126.4757
38	Lena River main channel, south of Stolb	26-Jun-2011	72.3705	126.6538
39	off Kurungnakh	26-Jun-2011	72.3334	126.2914
40	close to Samoylov Island	29-Jun-2011	72.3681	126.4738
41	close to Samoylov Island	29-Jun-2011	72.3681	126.4738
42	close to Samoylov Island	30-Jun-2011	72.3681	126.4738
43	close to Samoylov Island	30-Jun-2011	72.3681	126.4738
44	close to Samoylov Island	1-Jul-2011	72.3681	126.4738
45	close to Samoylov Island	1-Jul-2011	72.3681	126.4738
46	close to Samoylov Island	2-Jul-2011	72.3681	126.4738
47	close to Samoylov Island	2-Jul-2011	72.3681	126.4738

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1 Table 2. Particulate organic carbon (POC) contents in Lena Delta surface water (2009 to
 2 2011) given in milligram per liter (mg/L) and percent based on sediment dry weight (wt%) as
 3 well as atomic particulate organic carbon (POC) to particulate total nitrogen (PN) ratios. Data
 4 on individual samples can be found in the supplement (Table S4). Note that for Aug 2009
 5 there are only n=20 samples for POC (wt%), because the total suspended matter concentration
 6 was not determined for sample 19.

	POC [mg/L]	POC [wt%]	atomic POC:PN
<i>Lena Delta TSM Aug 2009</i>			
	<i>n=21</i>	<i>n=20</i>	<i>n=21</i>
mean	1.21	7.2	9.6
median	0.83	4.7	9.2
min	0.35	1.9	6.8
max	7.24	37.7	19.3
<i>Lena Delta TSM Jul/Aug 2010</i>			
	<i>n=13</i>	<i>n=13</i>	<i>n=13</i>
mean	0.57	3.05	7.6
median	0.47	3.05	7.8
min	0.15	1.42	3.7
max	1.30	4.74	10.3
<i>Lena Delta TSM late May 2011</i>			
sample code:	37	8.20	1.66
			7.5
<i>Lena Delta TSM late Jun/early Jul 2011</i>			
	<i>n=9</i>	<i>n=9</i>	<i>n=9</i>
mean	0.74	4.32	7.8
median	0.69	4.61	7.8
min	0.29	3.20	5.9
max	1.51	4.99	9.7

7

8

1 Table 3. Stable carbon isotope ($\delta^{13}\text{C}$) and radiocarbon composition (^{14}C) of Lena Delta first
 2 terrace soil profiles and surface water particulate organic matter (2009-2011). Soil profile
 3 samples are given in meters below surface (m b.s.). Not determined is denoted by *n.d.*

Sample code	$\delta^{13}\text{C}$ [‰ VPDB]	fMC^1	$1\sigma fMC$	$\Delta^{14}\text{C}$ [‰]	conv. ^{14}C age ² [yrs BP]	$1\sigma^{14}\text{C}$ age [yrs BP]	Lab ID
<i>Lena Delta first terrace soils</i>							
L09-12, 0.45m b.s.	-26.8	0.8084	0.0039	-197	1710	40	OS-84097
L09-12, 1.35m b.s.	-26.3	0.7311	0.0029	-274	2510	30	OS-84073
L09-12, 2.50m b.s.	-25.2	0.7023	0.0025	-303	2840	30	OS-84072
L09-12, 4.70m b.s.	-27.0	0.5708	0.0024	-433	4500	35	OS-84071
L09-12, 5.80m b.s.	-25.1	0.6275	0.0027	-377	3740	35	OS-84070
L09-28, 030m b.s.	-26.1	0.8015	0.0026	-204	1780	25	OS-84074
L09-28, 070m b.s.	-26.6	0.5430	0.0028	-461	4900	40	OS-84087
<i>Lena Delta Aug 2009</i>							
1	-30.5	0.7436	0.0029	-262	2380	30	OS-84096
2	-32.6	0.8173	0.0034	-189	1620	35	OS-84090
3	-30.9	0.8735	0.0031	-133	1090	30	OS-84093
4	-29.6	0.8259	0.0029	-180	1540	25	OS-84091
5	-31.3	0.8717	0.0031	-134	1100	30	OS-84098
6	-30.5	0.8524	0.0032	-154	1280	30	OS-84127
10	-29.8	0.8419	0.0032	-164	1380	30	OS-84101
11	-28.9	0.8458	0.0031	-160	1340	30	OS-84100
12	-30.6	0.8913	0.0031	-115	925	25	OS-84102
13	-29.9	0.8672	0.0036	-139	1140	30	OS-84133
14	-28.8	0.7971	0.0031	-209	1820	30	OS-84099
19	-34.2	0.9522	0.0042	-55	395	35	OS-84086
21	-27.1	0.8210	0.0028	-185	1580	25	OS-84088
<i>mean</i>	-30.4	0.8462	0.0032	-160	1353	30	
<i>standard deviation</i>	1.7	0.0480	0.0003	48	457	3	
<i>Lena Delta TSM Jul/Aug 2010</i>							
22	-29.7	0.8344	0.0029	-172	1450	30	OS-95088
24	-29.4	0.8201	0.0034	-186	1590	35	OS-95100
25	-28.3	0.8288	0.0030	-177	1510	30	OS-95266
26	-28.9	0.8001	0.0028	-206	1790	30	OS-95382
27	-28.9	0.8386	0.0034	-167	1410	30	OS-95268

28	-28.8	0.8046	0.0035	-201	1750	35	OS-95380
29	-28.9	0.8353	0.0117	-171	1440	110	OS-94853
30	-30.2	0.8389	0.0033	-167	1410	30	OS-95238
31	-28.6	0.6139	0.0021	-391	3920	25	OS-95239
32	-29.6	0.8390	0.0033	-167	1410	30	OS-95267
33	-29.8	0.8125	0.0144	-193	1670	140	OS-94857
35	<i>n.d.</i>	0.8299	0.0035	-176	1500	35	OS-95377
36	-30.4	0.8628	0.0150	-143	1180	140	OS-94858
<i>mean</i>	-29.3	0.8122	0.0056	-194	1695	54	
<i>standard deviation</i>	0.6	0.0594	0.0045	59	661	42	

Lena Delta TSM late May 2011

37	-26.5	0.6988	0.0028	-306	2880	30	OS-94760
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Lena Delta TSM late June/early July 2011

38	-28.3	0.8623	0.0030	-144	1190	30	OS-95378
42	-29.3	0.8558	0.0033	-151	1250	30	OS-95384
47	-28.5	0.8519	0.0117	-154	1290	110	OS-94854
<i>mean</i>	-28.7	0.8567	0.0060	-150	1243	57	
<i>standard deviation</i>	0.4	0.0043	0.0040	4	41	38	

1 ¹fMC=fraction modern carbon, ²conv. age=conventional radiocarbon age in years before
2 present [yrs BP], i.e. before 1950

3

4

1 Table 4. End-member values used for the binary mixing models based on POC:PN and $\delta^{13}\text{C}$,
 2 and for dual-carbon isotope three end-member mixing model. If not directly taken from the
 3 literature, individual values from the literature and this study used to calculate the end-
 4 members can be found in Tables S1-S3 in the supplement.

	Scenario 1 POC:PN		Scenario 2 $\delta^{13}\text{C}$		Dual-carbon isotope three end-member		
	riverine phytoplankton	soil	riverine phytoplankton	soil	riverine phytoplankton	Holocene soils	Ice Complex deposits
POC:PN	6 ± 1^1	23.7 ± 11	–	–	–	–	–
$\delta^{13}\text{C}$ [‰ vs. VPDB]	–	–	30.5 ± 2.5	-26.6 ± 1.0	30.5 ± 2.5	26.6 ± 1.0	-26.3 ± 0.67^3
$\Delta^{14}\text{C}$ [‰]	–	–	–	–	41.9 ± 4.2^2	-282 ± 133	-940 ± 84^3

5 ¹Meyers (1994) and references therein

6 ²average and standard deviation of atmospheric $\Delta^{14}\text{C}$ values from May-Aug 2009-2011 from
 7 Levin et al. (2013)

8 ³from Vonk et al. (2012)

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1 Table 5 Soil fractions calculated based on POC:PN ratios and $\delta^{13}\text{C}$ values and associated
 2 estimated ^{14}C concentrations of the soil-derived POM fraction. Soil fractions are given with
 3 standard deviation (1σ). $\Delta^{14}\text{C}$ values are given with lower quantile (q16) and upper quantile
 4 (q84) representing the 68% confidence interval (1σ for normal distributions). $\Delta^{14}\text{C}$ values
 5 lower than -1000‰ were marked as ‘fossil’. Not determined denoted by *n.d.*

sample code	POC:PN based estimates					plankton $\delta^{13}\text{C}$ -based estimates				
	fraction soil POM _{POC:PN}	$\Delta^{14}\text{C}_{\text{POC:PN}}$ [‰]	$\Delta^{14}\text{C}_{\text{POC:PN}}$ q16 [‰]	$\Delta^{14}\text{C}_{\text{POC:PN}}$ q84 [‰]	conv. $^{14}\text{C}_{\text{POC:PN}}$ age [yrs BP]	fraction soil POM _{$\delta^{13}\text{C}$}	$\Delta^{14}\text{C}_{\delta^{13}\text{C}}$ [‰]	$\Delta^{14}\text{C}_{\delta^{13}\text{C}}$ q16 [‰]	$\Delta^{14}\text{C}_{\delta^{13}\text{C}}$ q84 [‰]	conv. $^{14}\text{C}_{\delta^{13}\text{C}}$ age [yrs BP]
<i>Lena Delta TSM Aug 2009</i>										
1	0.33 ± 0.18	-884	fossil	-550	17,250	0.31 ± 0.17	-944	fossil	-585	23,100
2	0.32 ± 0.18	-688	fossil	-416	9,300	0.17 ± 0.12	fossil	-	-	fossil
3	0.30 ± 0.18	-535	fossil	-313	6,100	0.28 ± 0.16	-591	fossil	-354	7,120
4	0.26 ± 0.17	-811	fossil	-465	13,320	0.40 ± 0.20	-511	-967	-327	5,690
5	0.31 ± 0.18	-528	fossil	-314	5,970	0.24 ± 0.15	-681	fossil	-399	9,120
6	0.36 ± 0.19	-506	-998	-492	5,600	0.31 ± 0.17	-594	fossil	-363	7,180
7	0.27 ± 0.18	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
8	0.29 ± 0.18	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
9	0.38 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
10	0.38 ± 0.19	-506	-985	-322	5,600	0.38 ± 0.19	-500	-953	-317	5,510
11	0.32 ± 0.18	-595	fossil	-359	7,200	0.50 ± 0.21	-364	-655	-245	3,580
12	0.42 ± 0.20	-332	-625	-213	3,190	0.30 ± 0.17	-483	-981	-291	5,240
13	0.43 ± 0.20	-382	-709	-249	3,810	0.37 ± 0.19	-451	-899	-282	4,760
14	0.34 ± 0.19	-704	fossil	-434	9,720	0.51 ± 0.22	-447	-793	-307	4,700
15	0.38 ± 0.20	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
16	0.70 ± 0.16	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
17	0.36 ± 0.18	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
18	0.38 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
19	0.27 ± 0.17	-322	-718	-174	3,060	0.12 ± 0.09	-774	fossil	-407	11,890
20	0.38 ± 0.20	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
21	0.30 ± 0.20	-724	fossil	-413	10,280	0.75 ± 0.20	-261	-377	-214	2,370
<i>Lena Delta TSM Jul/Aug 2010</i>										
22	0.30 ± 0.18	-675	fossil	-402	8,970	0.39 ± 0.20	-505	-976	-322	5,590
24	0.30 ± 0.18	-708	fossil	-424	9810	0.43 ± 0.20	-491	-914	-320	5,370
25	0.37 ± 0.19	-544	fossil	-349	5100	0.59 ± 0.22	-330	-553	-237	3,160
26	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	0.50 ± 0.21	-456	-807	-308	4,830
27	0.44 ± 0.20	-431	-787	-284	3760	0.50 ± 0.21	-456	-679	-256	3,780
28	0.41 ± 0.20	-544	fossil	-355	5360	0.51 ± 0.21	-380	-756	-296	4,490
29	0.35 ± 0.18	-570	fossil	-353	5890	0.50 ± 0.21	-384	-690	-258	3,830
30	0.26 ± 0.17	-764	fossil	-437	11700	0.34 ± 0.18	-581	fossil	-360	6,930
31	0.31 ± 0.18	fossil	-	-	fossil	0.54 ± 0.22	-754	fossil	-536	11,210
32	0.34 ± 0.19	-564	fossil	-349	6190	0.40 ± 0.20	-476	-903	-306	5,130
33	0.32 ± 0.18	-694	fossil	-419	8890	0.38 ± 0.19	-579	fossil	-366	6,890

34	0.36 ± 0.21	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
35	0.39 ± 0.20	515	-997	-329	5190	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
36	0.12 ± 0.13	fossil			<i>n.d.</i>	0.34 ± 0.18	-510	fossil	-312	5,670

Lena Delta TSM late May 2011

37	0.13 ± 0.13	fossil			<i>n.d.</i>	0.80 ± 0.19	-393	-539	-341	3,950
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Lena Delta TSM late Jun/early Jul 2011

38	0.43 ± 0.19	-391	-704	-258	2870	0.59 ± 0.22	-274	-460	-196	2,510
39	0.50 ± 0.20	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
41	0.39 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
42	0.41 ± 0.19	-429	-798	-280	3340	0.44 ± 0.21	-394	-738	-256	3,970
43	0.43 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
44	0.41 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
45	0.43 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
46	0.44 ± 0.19	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>	<i>n.d.</i>
47	0.40 ± 0.19	-451	-848	-290	3620	0.56 ± 0.22	-310	-534	-215	2,920

1

2

1 **Figure captions**

2 Figure 1. A) Lena River catchment area within the northern hemisphere permafrost zone (map
3 by Hugo Ahlenius, UNEP/GRID-Arendal, see www.grida.no/graphicslib/detail/permafrost-
4 [extent-in-the-northern-hemisphere_1266](http://www.grida.no/graphicslib/detail/permafrost-); source data from Brown et al. 1998), B) Lena Delta
5 and Buor Khaya Bay sampling sites from 2009 to 2011 analyzed for radiocarbon content (see
6 also table 1).

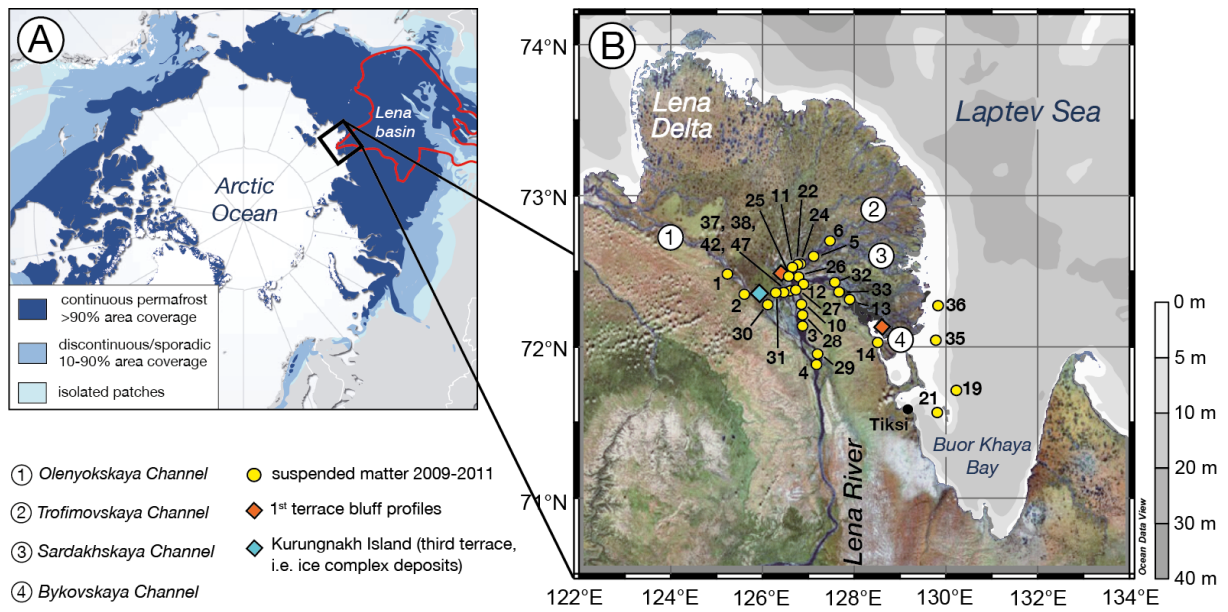
7 Figure 2. Spatial distribution of organic carbon concentrations, POC:PN ratios and stable and
8 radiocarbon isotopic composition in surface water total suspended matter (TSM) samples
9 from 2009-2011. TSM concentrations of the years 2009 to late May 2011 (panels A-C) taken
10 from Winterfeld et al. (2015, companion paper).

11 Figure 3. Stable and radiocarbon isotopic values of Lena Delta surface water POM of A) this
12 study and literature data as well as B) estimated isotopic data of soil-derived POM based on
13 POC:PN and $\delta^{13}\text{C}$ ratios. Ranges for different end-members for topsoil, ice complex, and
14 marine are taken from the literature.

15 Figure 4. Results of dual carbon-isotope ($\delta^{13}\text{C}$, $\Delta^{14}\text{C}$) three end-member mixing model
16 showing the fractions for riverine phytoplankton, Holocene soils, and Pleistocene Ice
17 Complex deposits contributing to individual surface water POM samples. The end-member
18 used in the model can be found in Table 4. Individual values comprising the Holocene soil
19 $\delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ end-member are given in Tables S2 and S3 in the supplement. Note the bulk
20 POM $\Delta^{14}\text{C}$ values are ordered from the lowest to the highest and the respective sample IDs
21 are given on top axis.

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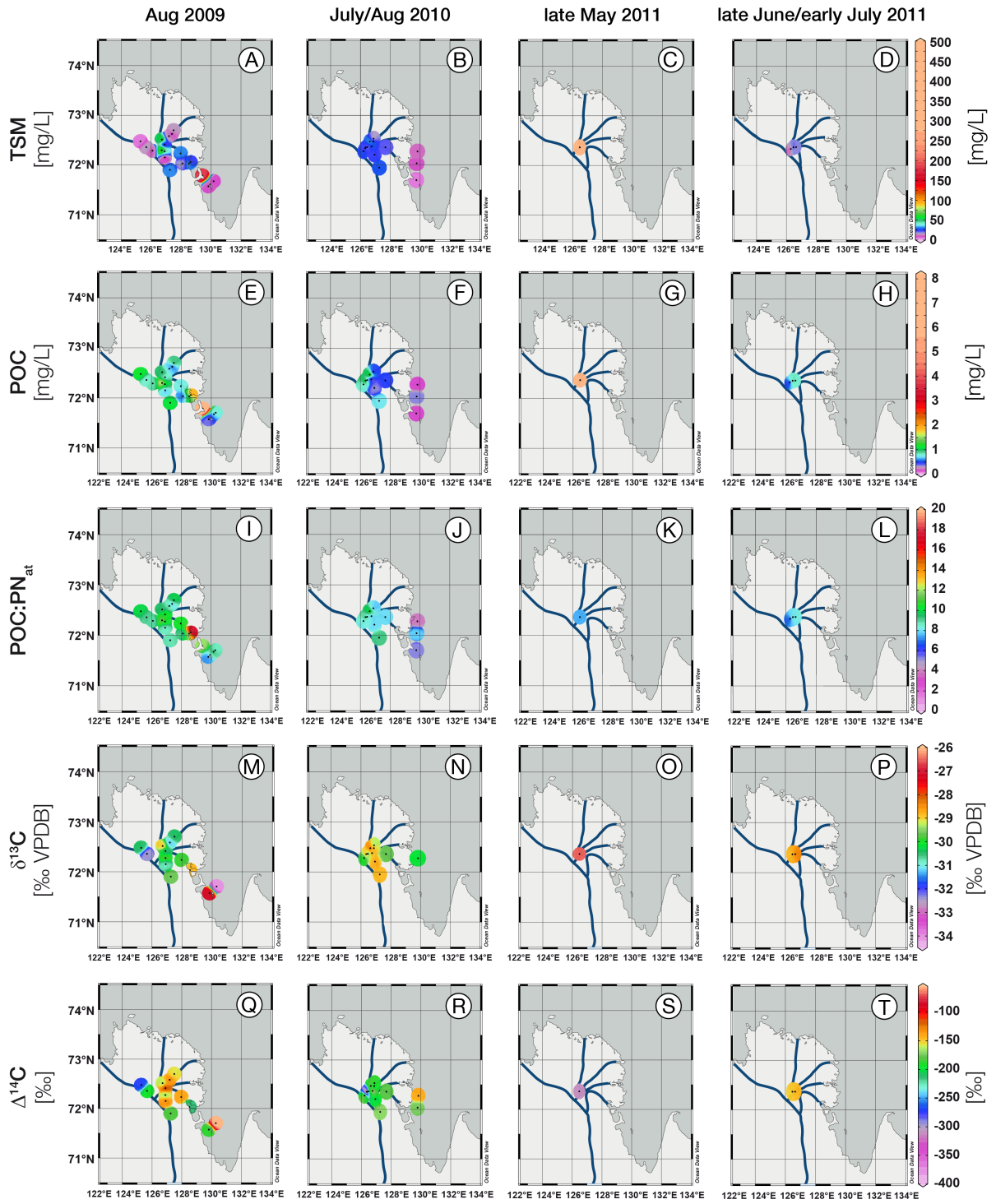


1

2 Figure 1.

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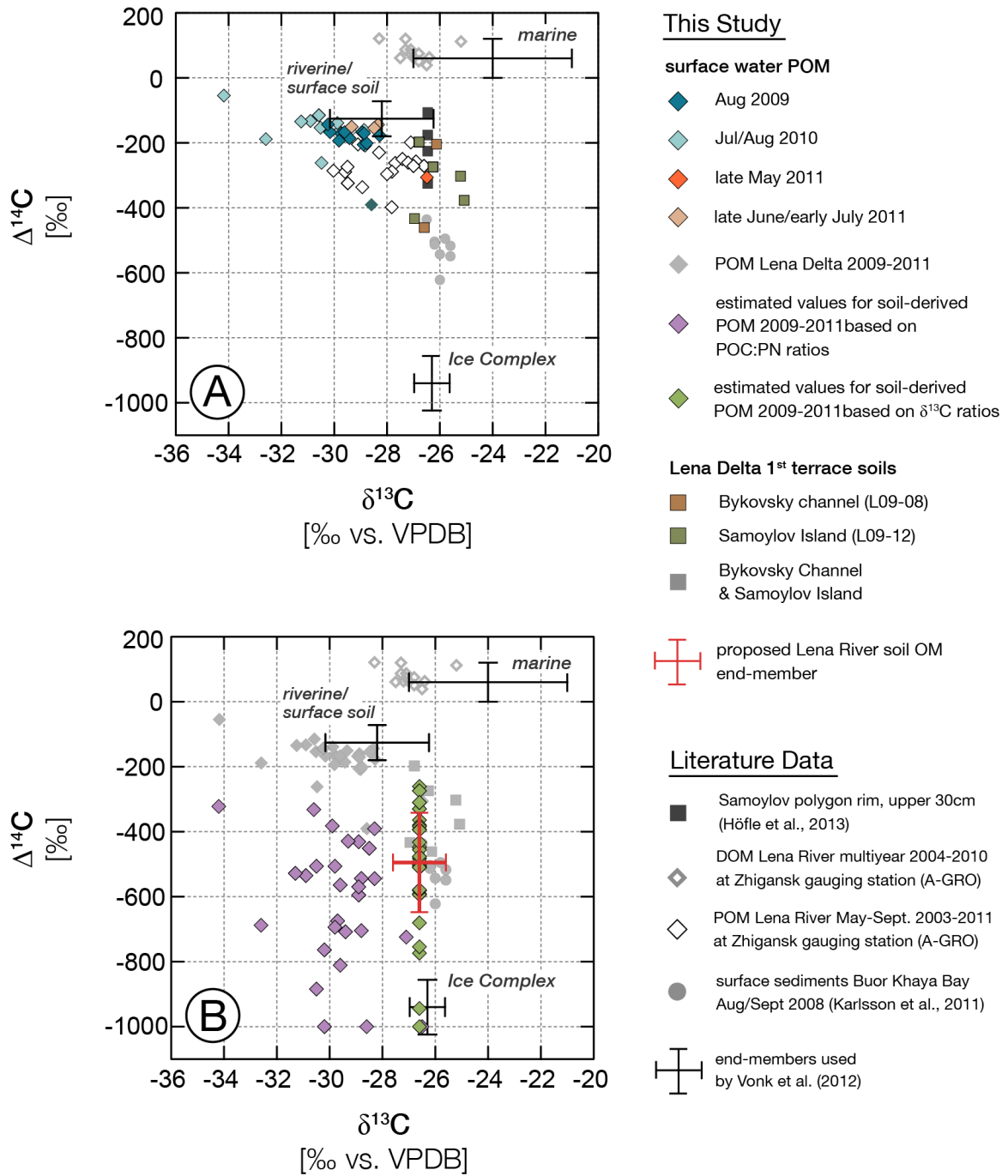
4



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2 Figure 2.

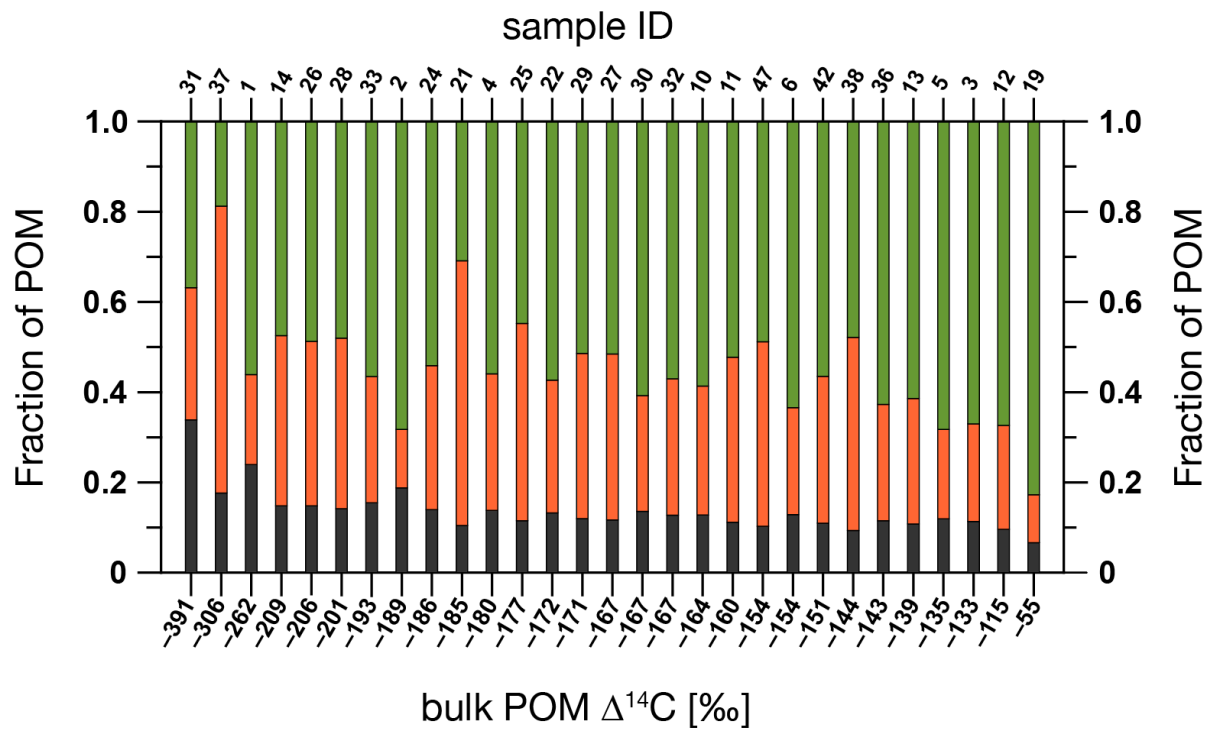
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2 Figure 3.

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1

2 Figure 4.