## A model of offshore OC and GDGT delivery

The model considers the export of GDGT biomarker molecules and organic carbon (OC) across the entire area of the ESAS included in this study. It is a simplified model in which a small number of processes and parameters are able to replicate the observed patterns across the ESAS. The model considers the delivery of sediment from both rivers and coastal erosion, and the organic carbon and GDGTs associated with this material. Combining this with marine primary productivity we can model the delivery of sediment, terrestrial organic carbon and marine carbon to each position on the ESAS, and calculate the BIT index and $\delta^{13}C_{SOC}$ values that would be generated by that delivery.

Rivers are point sources of sediment, OC and biomarkers, distributed along the ESAS coastline. Measurements in this study showed that brGDGT concentrations were highest at the mouths of GRARs. From the river mouth, material was modelled as spreading out in a 1/distance radial pattern, such that sediment, OC and GDGTs from fluvial sources were primarily deposited close to the river mouth, and concentrations dropped rapidly offshore. For simplicity, ocean currents were ignored, both surface and deep. Since GRAR outflow points are distributed 100s of $\mathrm{km}$ apart along the shoreline, the effects of interactions between river inputs was ignored - each position on the ESAS was modelled as only being affected by the closest river.

Measurements of the Kolyma River and associated lakes (**?**), as well as the Yenisey River (**?**) and nearshore marine sediments from this study showed that brGDGTs were abundant in fluvial sediment. BIT values of 0.99 to 1 (Kolyma River, **?**) and 0.95 to 1 (Yenisey River, **?**) showed that there was very little crenarchaeol. OC and GDGT concentrations in fluvial material were parameterized using samples from this study collected closest to the river mouths. Single values for fluvial sediment output, OC and GDGT concentrations were applied to all rivers. $\delta^{13}C_{SOC}$ values were set at -28.1 ‰in the Laptev Sea and -26.3 ‰in the ESS (**?**).

Coastal erosion is a major source of sediement and to the ESAS, and is prevalent along a majority of the East Siberian Arctic coastline (**??**). The delivery of sediment, OC and GDGTs from coastal erosion was modelled as a linear source, assuming that all sections of the coastline were acting as a source of material. This leads to sediment, OC and GDGT deposition rates decreasing proportional to the distance from source, in a linear fashion. OC and GDGT input from coastal erosion was parameterized from measurements in this study and published data (**??**). Measurements from two vertical Yedoma permafrost transects showed that GDGT concentrations were low throughout, so the coastal erosion sediment was a minor source of GDGTs to the ESAS. OC concentrations in the Yedoma samples was similar to fluvial sediments. Coastal-sourced sediment was given a $\delta^{13}C_{SOC}$ signature matching the source area - -27.1 ‰in the Laptev Sea and -26.0 ‰in the ESS.

Degradation during transport is an important consideration for terrestrial OC and GDGTs, however it is currently very poorly understood and could only be parameterized as a simplified process. Since transport exposes OC and GDGTs to oxygenated water, degradation of both terrestrial OC and GDGTs was modelled as a function of the distance travelled from source. The model used a linear relationship between distance travelled and proportion degraded, such that by a given distance offshore (defined as 800 km) all of the material was modelled as having been degraded. Obviously this is a simplification, since there are some recalcitrant fractions of OC that would certainly survive transport across the whole shelf - graphite particles have been observed far across the ESAS using the Raman Spectroscopy technique of **?** - but in the absence of a comprehensive degradation study in this region it is not possible to include a more thorough model.

In the model, marine primary productivity produces both marine OC and crenarchaeol. Low-level production of brGDGTs in marine settings (**?**) was treated as insignificant and ignored. Observations of crenarchaeol distribution in the ESAS sediments (Figure 3b), and of marine biomarkers in this region (**?**), showed that productivity was maximum at intermediate distances across the shelf (76 - 79 °N), and reduced close to the shore and far offshore. These areas exhibit winter sea-ice cover for longer amounts of the year, which will reduce primary productivity, whilst the region between the polar ice cap and the terrestrially-bound fast ice contains open-water polynyas (**?**). A parabolic distribution was used to model the production of crenarchaeol. This varied from 4.2 $\mathrm{mgm^{-2}\ y^{-1}}$ at

**Table 1.** Table S1: Physical properties of major rivers draining East Siberia

| River | Basin Area[1] $10^3$ km$^2$ | Water Discharge[1] km$^3$ y$^{-1}$ | Sediment Discharge[1] $10^6$ ty$^{-1}$ | Continuous Permafrost[1,2] % of basin area |
|---|---|---|---|---|
| Lena | 2448 | 523 | 20.7 | 71 |
| Yana | 225 | 32 | 4.0 | 100 |
| Indigirka | 360 | 54 | 11.1 | 100 |
| Kolyma | 647 | 122 | 10.1 | 99 |

[1]?
[2]?.

$0$ km via 17 $\mathrm{mgm}^{-2}$ $\mathrm{y}^{-1}$ at 290 km to zero productivity at 625 km. However, there is very poor correlation between crenarchaeol concentrations and $\delta^{13}\mathrm{C}_{SOC}$ across the shelf (r$\hat{2}$ = 0.23; compare Figures 3b and S2d). This suggests that there are marine sources of OC unrelated to the production of Cren. In the absence of more precise data, marine OC production was modelled as a uniform 0.4 $\mathrm{gm}^{-2}\mathrm{y}^{-1}$. These model parameters are collated in Table S3.

Each point on the ESAS was evaluated using GIS software that measured the distance to the closest river mouth and the closest coastline. These were given the values $\mathrm{D}_{riv}$ and $\mathrm{D}_{coast}$ respectively. This allowed the delivery of sediment, OC and GDGTs to be modelled for each location. Fluvial OC and GDGTs are a function of 1/$\mathrm{D}_{riv}$. Yedoma OC and GDGTs are a function of $\mathrm{D}_{coast}$, as are marine OC and crenarchaeol. Having modelled the delivery of sediment, OC and GDGTs for each position on the shelf, TOC, $\delta^{13}\mathrm{C}_{SOC}$ and BIT values were calculated for comparison with measured data and application to the whole shelf carbon cycle.

(R1)

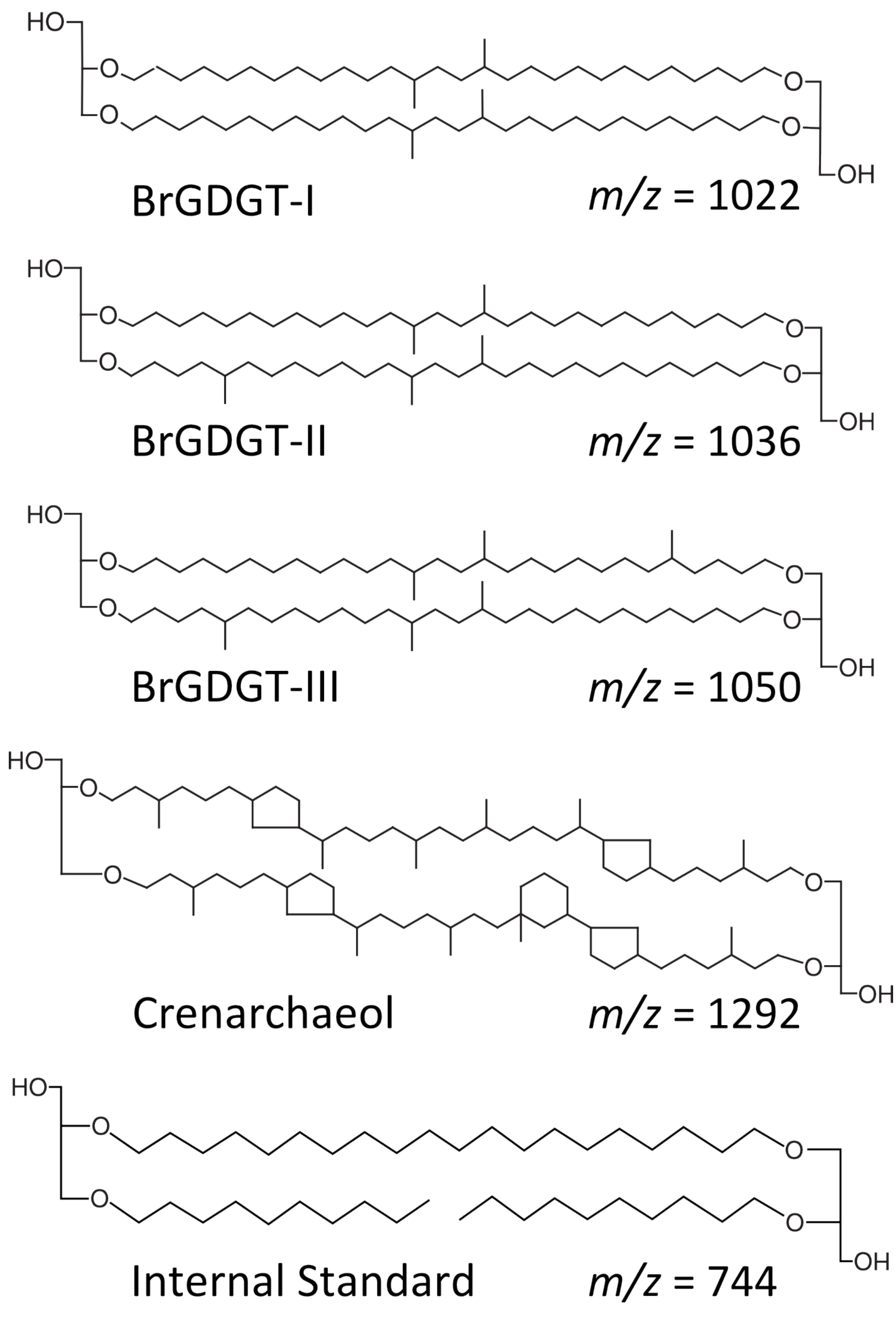


**Figure 1.** Figure S1: Structures of Branched GDGTs, Crenarchaeol and the synthetic $C_{46}$ internal standard measured in this study.

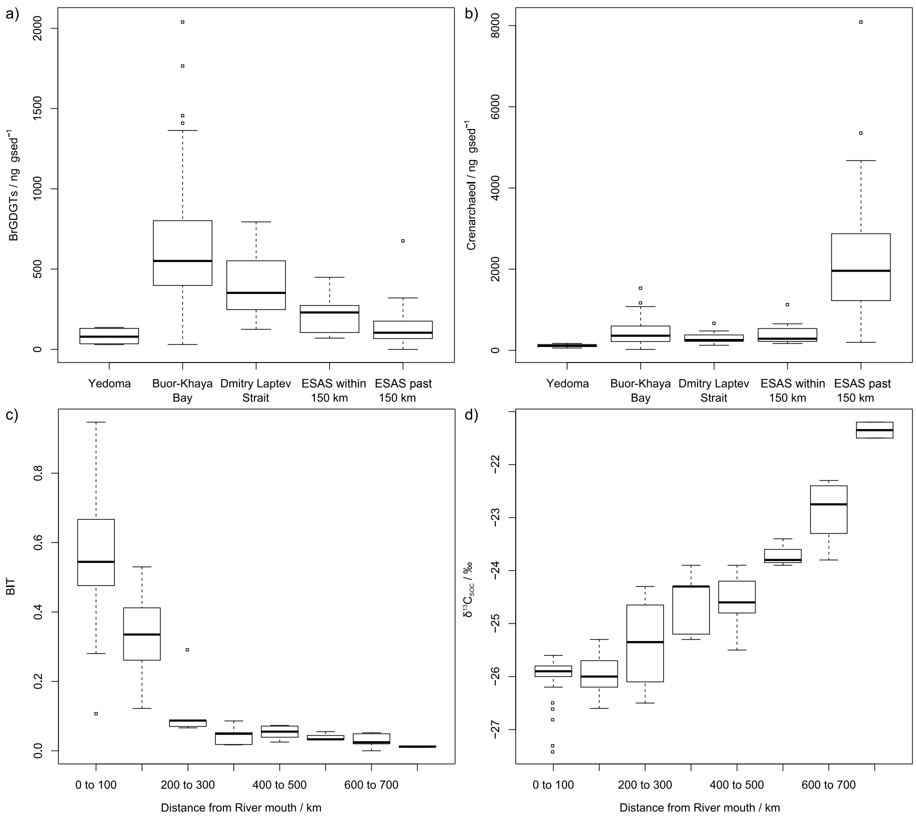


**Figure 2.** Figure S2: Boxplots summarising the concentrations of a) brGDGTs and b) Crenarchaeol on the ESAS, grouped by sampling regions. Also c) BIT index and d) $\delta^{13}C_{SOC}$ grouped by distance from river mouths. Thick lines show the median values, boxes the $25^{th}$ and $75^{th}$ percentiles, whiskers the maximum and minimum values within 1.5 times the inter-quartile range and square symbols outliers beyond this threshold.

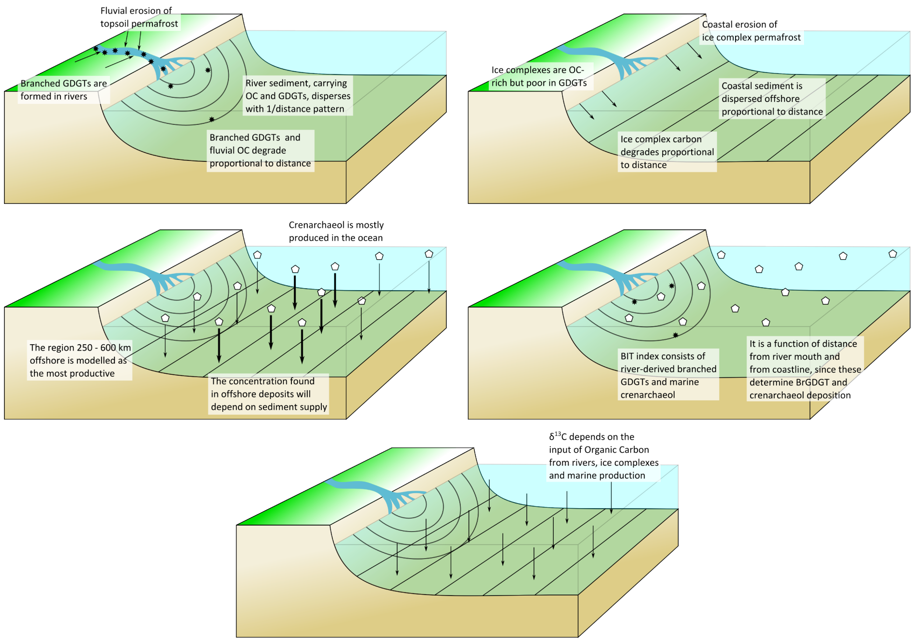


**Figure 3.** Figure S3: Cartoon demonstrating the principles behind the model used to understand carbon export and degradation on the ESAS.