Tracing soil organic matter from source to sink

Jung-Hyun Kim[1,*], Claudia Zell[1], Patricia Moreira-Turcq[2], Marcela Andrea Pérez[3], David Hollander[4], Dorthe Klitgaard Kristensen[5], Roselyne Buscail[6], Jaap S. Sinninghe Damsté[1]

[1]Royal Netherlands Institute for Sea Research (NIOZ), The Netherlands, [2]IRD-LMTG-HYBAM, France, [3]UFAM, Brazil, [4]University of South Florida, USA, [5]Norwegian Polar Institute, Norway, [6]CEFREM-CNRS UMR 5110, France

***E-mail: Jung-Hyun.Kim@nioz.nl**

1. Introduction:

The transport of terrestrial organic matter (OM) to coastal sediments represents a significant flux in the global carbon cycle. Although a large range of bulk and molecular proxies for terrestrial OM is available, quantification of the relative inputs of terrestrial OM to marine sediments is still difficult. The incomplete understanding of the transfer of terrestrial OM from land to the ocean is probably due to the lack of diagnostic (geochemical) proxies especially for soil OM which accounts for two third of the total terrestrial carbon budget. Recently, several developments have however led to new insights into the recognition of soil OM in marine environments. The Branched and Isoprenoid Tetraether (BIT) index (Hopmans et al., 2004, Fig. 1) has been introduced as a proxy to trace soil OM input from land to the marine environments (e.g. Walsh et al., 2008; Kim et al., 2009). This index is based on the relative abundance of non-isoprenoidal glycerol dialkyl glycerol tetraethers (GDGTs) versus a structurally related isoprenoid GDGT "crenarchaeol". Branched GDGTs are produced by anaerobic bacteria thriving in soils (Weijers et al., 2006), whereas crenarchaeol is produced predominantly by marine Crenarchaeota (Sinninghe Damsté et al., 2002). We discuss the use of the BIT index to trace soil OM input in contrasting depositional settings: the Rhone prodelta (NW Mediterranean), the fjords of Svalbard (Arctic Ocean), and the Amazon shelf and fan (tropical Atlantic).

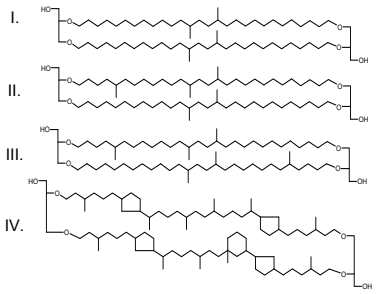

Fig. 1. Glycerol dialkyl glycerol tetraethers (GDGT) structures and the definition of the BIT index. I, II, and III indicate the branched GDGTs and IV is crenarchaeol.

2. Results:

Gulf of Lions (NW Mediterranean):

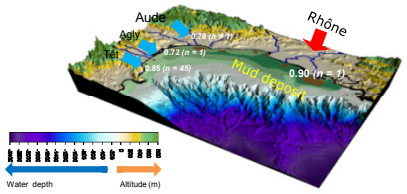

Fig. 2. We investigated suspended particulate matter (SPM) collected in the Rhône River and its tributeries (Doubs, Saône, Ain, Isère, and Durance) and other smaller Mediterranean rivers. BIT values of the Rhône River are comparable to those of its tributaries. The BIT value of the Rhône River at Arles (0.9, *n=1*) is higher than those of smaller Mediterranean rivers flowing into the Gulf of Lions.

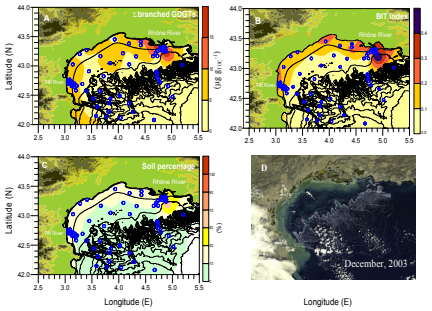

Fig. 3. In the Gulf of Lions, BIT values range from 0.01 to 0.85, with higher values along the coast compared to those offshore. The soil OM contributions to the total organic carbon (TOC), estimated based on the BIT index, are >10% along the coast, while those from the outer shelf and the continental slope are below 10% (Kim et al., 2010). The spatial distribution patterns of GDGT parameters are similar to the MODIS image of the Gulf of Lions showing across and along-shelf dispersion of the river plumes occurred in December, 2003 (Guillén et al., 2006).

Fjords of Svalbard (Arctic Ocean):

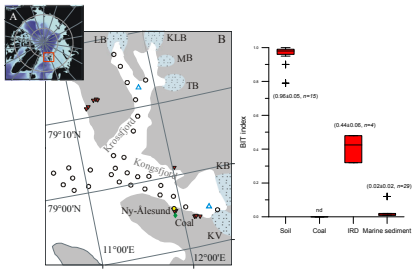

Fig. 4. (A) Map of the Arctic Ocean. (B) Sampling locations of marine surface sediment (O), IRD (Δ), soil (▽), and coal (♦). LB, KLB, MB, TB, KB, and KV indicate Lilliehöökbreen, Kollerbreen, Mayerbreen, Tinayrebreen, Kongsbreen, and Kongvegen, respectively. The BIT index of Svalbard soils was close to, as is typically found for soils. BIT values of IRD were much lower, while those of marine sediments were generally low.

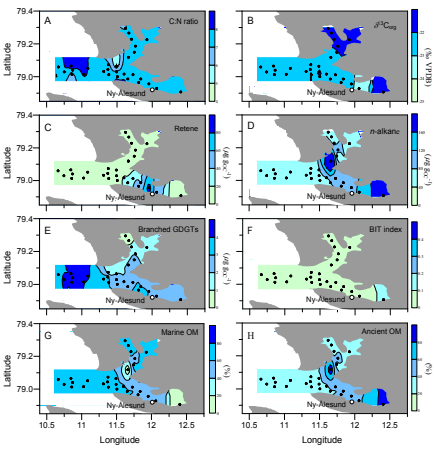

Fig. 5. Bulk geochemical parameters suggest a predominant marine contribution to sedimentary OM. The BIT index indicates that soil OM contribution to the marine sediments is minor. However, the parameters of retene, *n*-alkanes, and the depleted bulk radiocarbon content ($\Delta^{14}C$ value) suggest that ancient OM of both coal-derived and mature IRD-derived OM is being buried in the Kongsfjord-Krossfjord system of Svalbard in the high Arctic.

Amazon shelf & fan (tropical Atlantic):

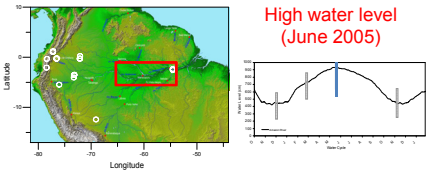

Fig. 6. Sampling locations of soil (O) and SPM in the red box in the Amazon basin. The SPM samples were collected during the high water level in June, 2005.

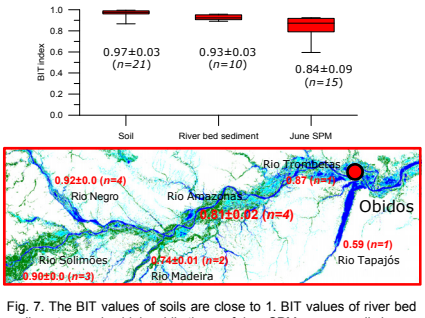

Fig. 7. The BIT values of soils are close to 1. BIT values of river bed sediments are also high, while those of river SPM are generally lower, varying among different tributaries.

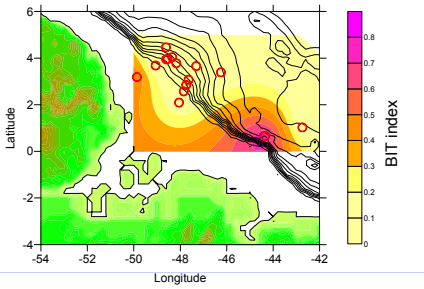

Fig. 8. The BIT values of marine sediments collected in the Amazon fan in 2010 are generally around 0.1, except for three sites with enhanced values (0.4-0.8). This suggests that deposition or preservation of soil organic matter are higher at those sites located on the continental shelf and slope.

4. Future work:

We will continue to work on soils and SPM collected in the Amazon watershed and marine surface sediments as well as SPM sampled in the Amazon shelf and fan. GDGT parameters will be compared with other geochemical parameters. This will further shed light on the potential of the BIT index for tracing soil OM input from land to the ocean and quantifying its fluxes.

Reference:

Hopmans, E.C., J.W.H. Weijers, E. Schefuß, L. Herfort, J.S. Sinninghe Damsté, and S. Schouten, A novel proxy for terrestrial organic matter in sediments based on branched and isoprenoidtetraether lipids. Earth Planet. Sci. Lett. 224, 107-116, 2004.

Kim, J.-H., B. Zarzycka, R. Buscail, F. Peters, J. Bonnin, W. Ludwig, S. Schouten, and J.S. Sinninghe Damsté, Factors controlling the Branched Isoprenoid Tetraether (BIT) Contribution of river-borne soil organic carbon to the Gulf of Lions (NW Mediterranean). Limnol. Oceanogr.,55, 507–518, 2010.

Walsh, E.M., A.E. Ingalls, and R.G. Keil. Sources and transport of terrestrial organic matter in Vancouver Island fjords and the Vancouver-Washington Margin: A multiproxy approach using d13Corg, lignin phenols, and the ether lipid BIT index. Limnol. Oceanogr. 53, 1054-1063, 2008.

Sinninghe Damsté, J.S., E.C. Hopmans, S. Schouten, A.C.T. van Duin, and J.A.J. Geenevasen, Crenarchaeol: the characteristic core glycerol dibiphytanyl glycerol tetraether membrane lipid of cosmopolitan pelagic crenarchaeota. J. Lipid Res., 43, 1641-1651, 2002.

Weijers, J.W.H., S. Schouten, E.C. Hopmans, J.A.J. Geenevasen, O.R.P. David, J.M. Coleman, R.D. Pancost, and J.S. Sinninghe Damsté, Membrane lipids of mesophilic anaerobic bacteria thriving in peats have typical archaeal traits. Environ. Microbiol., 8, 648-657, 2006.

Acknowledgement:

We thank to J. Ossebaar. M. Kienhuis, and E. Hopmans (NIOZ) for analytical support. Thanks also go to V. Willmott, F. Peterse, N. Koç, other participants, and the crew of the SciencePub International Polar Year cruises on the R/V Lance from the Norwegian Polar Institute. This study was carried out within the ERC PACEMAKER (Past Continental Climate Change: Temperatures from Marine and Lacustrine Archives) and ERG SOURCE (Tracing Amazon soil organic carbon input from land to the ocean) projects. This work was also supported by the CARBAMA (Carbon biogeochemistry and atmospheric exchanges in the Amazon River system), the CHACCRA (Climate and Human induced Alterations in Carbon Cycling at the River-seA connection), and EXTREMA (Episodes météo-climatiques extrêmes et redistribution des masses sédimentaires et des polluants associés au sein d'un système côtier) projects funded by the French National Research Agency.