Sea ice in the paleoclimate system

1st Sea Ice Proxies (SIP) Working Group workshop, Montréal, Canada, 7-9 March 2012

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Sea ice is a complex parameter that is difficult to reconstruct from indirect observations. While climate scientists often refer to sea ice as a purely physical parameter, geoscientists reconstruct past sea ice assuming it plays a role in the biogeochemistry of seawater, and thus on primary productivity and trophic structure of the planktonic populations (e.g. Meier et al. 2011). Moreover, whereas climatologists and modelers examine sea ice at hemispheric scale, geoscientists make reconstructions from coring sites where small-scale processes may obscure larger-scale sea ice behavior relevant to the climate system. Nevertheless, geoscientists have unique tools to contribute to the understanding of long-term sea ice dynamics by providing pictures of past sea ice states. This is the overarching objective of the PAGES Sea Ice Proxies (SIP) working group, which was created in 2011.

To achieve the objective of documenting sea ice in the paleoclimate system with the best possible coverage and accuracy, an assessment of each proxy and the development of multi-proxy approaches are both necessary. During the first workshop, scientists with physical, chemical, and biological backgrounds met to assess the reliability and use of sea ice indicators recovered in marine sediments and ice cores, and the robustness of calibration with instrumental data. The geographical and temporal ranges of application of the different proxies were also considered.

Sea ice proxies include chemical tracers in ice cores such as methanesulfonic acid and sea salt, which relate to regional circum-ice-cap sea ice extent (Röthlisberger and Abram 2009). Most sea ice proxies, however, consist of biogenic remains recovered from marine sediment such as diatoms, foraminifers, ostracods and dinocysts, as well as the IP25 biomarker (a C25 mono-unsaturated hydrocarbon). Because productivity in sea ice environments mostly occurs close to the ice edge in spring and summer, most biogenic proxies relate to the occurrence of seasonal sea ice. It is more difficult to quantify the seasonality of the ice extent, although diatom and dinocyst assemblages yield information about the yearly extent of the sea ice cover in the Southern Hemisphere (e.g. Crosta et al. 2004) and Northern Hemisphere (e.g. de Vernal et al. 2008), respectively. IP25 and related biomarker indices offer great promise for reconstruction of sea ice (e.g. Belt et al. 2007; Müller et al. 2011), but large-scale calibrations are still needed and the available data suggest primarily regional relationships. Another difficulty is the identification of multiyear ice because of the extremely low productivity of such environments. However, the occurrence of an ostracod species, parasitic of amphipods living in perennial sea ice environments, may lead to inferences about multiyear ice (Cronin et al. 2010). The shell of *Neoquoboquadrina pachyderma,* which is the only planktonic foraminifer species found in sea ice environments, may yield an isotopic signature providing clues on sea ice production rates (Hillaire-Marcel and de Vernal 2008).

Each sea ice proxy has limitations and uncertainties. Diatoms have allowed circum-Antarctic sea-ice extent reconstructions, but limitations remain where the signal is affected by opal dissolution. Other uncertainties come from the relationship to sea ice that is often indirect, as in the case of dinocyst, foraminifer and ostracod assemblages. In addition, taxonomical heterogeneity of populations in space may be related to endemism or to the development of genotypes having different ecological affinities, which make each biogenic proxy applicable mostly at a regional scale. Hence the Arctic-subarctic and circum-Antarctic have to be considered as distinct sea ice ecosystems with very different biogenic characteristics.

Reconstructing past sea ice is a challenge, which has to be addressed based on proxies offering complementary local to regional information on sea ice occurrence. The SIP Working Group will publish a special issue of *Quaternary Science Reviews* entitled "Sea ice in the paleoclimate system: modeling challenges and status of proxies" in 2013. The next step is to combine results with their respective uncertainties for multi proxy data integration and hemispheric scale sea ice reconstructions of Holocene and Last Glacial Maximum time slices. This will be the focus of the July 2013 rendezvous of the SIP Working Groupin Cambridge, UK.

Figure 1: Sea ice edge as a productive environment (photograph from the Southern Ocean and provided by Claire Allen, British Antarctic Survey, UK).

References

Belt ST et al. (2007) *Organic Geochemistry* 38: 16-27

Cronin TM et al. (2010) *Quaternary Science Reviews* 29: 3415-3429

Crosta X, Sturm A, Armand L, Pichon JJ (2004) *Marine Micropaleontolology* 50: 209-223

de Vernal A et al. (2008) In: E. Weaver (Ed) *Arctic Sea ice Decline: Observations, Projections, Mechanisms, and Implications,* AGU Monograph Series 180: 27-45

Röthlisberger R and Abram N (2009) *PAGES news* 17(1): 24-26