

Reconstructing past sea ice

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The recent rapid reduction in the extent and volume of Arctic sea ice makes it especially urgent to obtain long time series that can allow us to put recent events in context. The satellite dataset reaches only 40 years into the past, while syntheses using ship and aircraft observations have been taken back to the late 19th century. Before that, we are reliant almost entirely on proxy data – from marine sediments, ice cores, and coastal material, each providing evidence of past sea ice presence or absence.

However, there is generally a complex chain of processes connecting ice extent or presence to the measured proxy. An assessment of the basis for each individual proxy was the main business of the first SIP workshop in Montréal in 2012 (de Vernal et al. 2013a). This resulted in a special issue, entitled "Sea Ice in the Paleoclimate System: the Challenge of Reconstructing Sea Ice from Proxies" in the journal, *Quaternary Science Reviews*. Among the 18 papers published, there are three authoritative review papers, one on the use of dinocysts to estimate northern hemisphere sea ice (de Vernal et al. 2013b), another on the biomarker IP25 (Belt and Müller 2013), and the last on ice core proxies of sea ice extent (Abram et al. 2013). An introductory paper (de Vernal et al. 2013c) provides a table highlighting the advantages and disadvantages of each method.

The second workshop took this as its starting point and proceeded to explore the new ideas that had emerged in the last year. Although most of the work discussed was based on proxies discussed at the first workshop, a new candidate proxy in ice cores (halogens) was presented, and the use of material such as driftwood and sedimentological material was also considered.

The main issue for the workshop was to consider ways in which multiple proxies from many sites can be used together to create credible reconstructions of sea ice proxies. Issues arise at each stage (Fig. 1). For some proxies, such as the biomarker IP25, even ensuring comparable analytical results is challenging. A recent intercomparison exercise was presented, and based on this, new recommendations for standardizing analytical methods will be prepared. Once the measurement is complete, it is often reported in terms of a sea ice property, such as seasonal extent, presence/absence, or months of ice cover. The basis for calibrating each proxy against a particular property needs careful examination. Study of the modern processes that link ice to, for example, a biological vector that may be present only seasonally, and to its deposition in sediment, is essential. The workshop participants were urged to take

advantage of existing field campaigns in each polar region, led by people studying current sea ice conditions, to gather further data.

Perhaps the biggest challenge is to synthesize data from different proxy types, often reporting different ice properties, into a single reconstruction. Few multi-proxy comparisons exist, and the meeting participants agreed to set up such a study on some exemplar marine core sections. Despite these problems, reconstructions have been attempted, and the workshop was presented with first efforts at Holocene time slices for both the Arctic and Southern Ocean, and for the last interglacial in Antarctica. Discussion centered on how to improve and enhance these efforts, and how to best report the ice conditions in a way that is compatible both with modern datasets and with the requirements of sea ice modelers. Completion of such work will be the main task

for the third workshop, to be held in Bremerhaven, Germany, on 23-25 June 2014.

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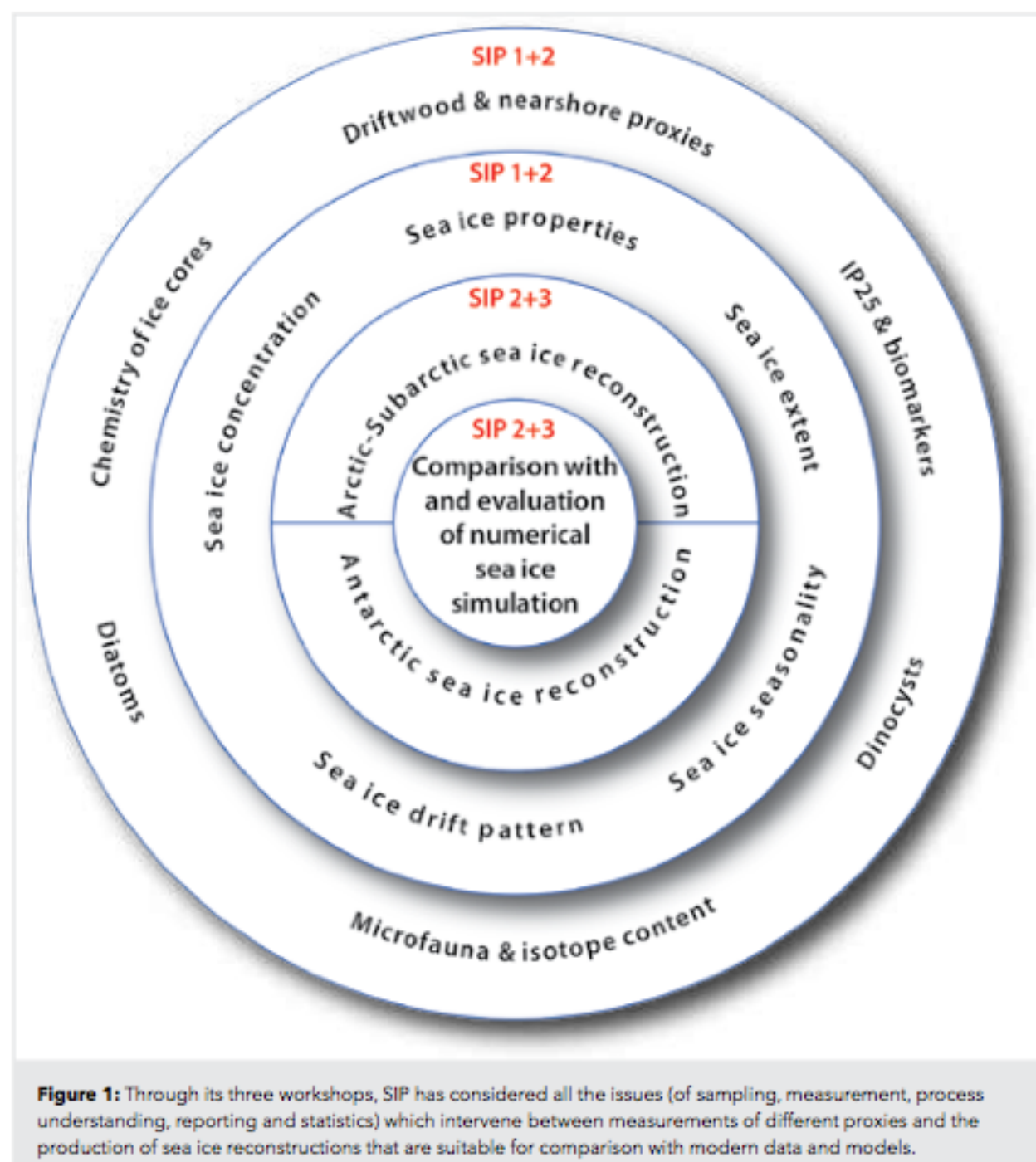


Figure 1: Through its three workshops, SIP has considered all the issues (of sampling, measurement, process understanding, reporting and statistics) which intervene between measurements of different proxies and the production of sea ice reconstructions that are suitable for comparison with modern data and models.