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Ice Core Young Scientists spotlight new developments in ice-core science

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This special issue highlights recent advances in ice-core paleoclimatology led by early-career researchers (ECRs) and reflects the efforts of the Ice Core Young Scientists (ICYS; pastglobalchanges.org/icys) workshop in October 2022 in Crans-Montana, Switzerland (pastglobalchanges.org/calendar/26967). These articles are dedicated to promoting ECR research at the frontiers of ice-core science, and they recognize the recent surge of development in novel ice-core proxies, ice-core dating, and modeling techniques over the last decade. This endeavor is divided into areas at the heart of our field today: interpretation of ice-core proxies such as impurities, water isotopes, and gases; paleo-chronological constraints; and data integration with models to reconstruct paleoclimate scenarios.

The first set of articles feature novel environmental proxies based on ice-core impurities, with a focus on analytical techniques and applications. Increasing observations of climate-relevant aerosols, and assessing their impact on the climate system, is a pressing need, particularly over the Southern Ocean where the unique and poorly observed aerosol properties limit the ability of global climate models to correctly simulate the radiative budget. Novel analytical techniques show great promise for characterizing the size, shape, and composition of ice-core impurities, providing crucial data for radiative transfer models. New insights into the radiative properties of aerosols are highlighted by Lomax-Vogt et al. (p. 90), who describe the recent advances in ice-core single-particle analysis, while Cremonesi and Ravasio (p. 92) review innovative ice-core optical techniques. Burgay (p. 94) explores the potential of non-target screening of ice-core organic compounds as a previously untapped archive of atmospheric composition.

Trapped bubbles of ancient air are one of the most unique components of the ice-core record (Fig.1a). These gases provide a direct window to study the atmosphere of the past. Among recent advances, Shackleton (p. 96) shows how noble gas ratios in the ice-core record are used to reconstruct past mean ocean temperatures. Interpretation of the gas record in older ice samples presents a challenge, especially where the stratigraphic order has been disturbed. Current efforts to extract paleoclimatic information are described by Yan (p. 98) who reviews the use of blue ice areas – where very old ice has flowed to the surface – to record changes in million-year-old greenhouse gases.

Water isotopes are a fundamental component of ice-core temperature reconstructions. Yet accurate calibration of this traditional paleothermometer is hindered by diffusion, precipitation intermittency, and wind redistribution processes, as Casado and Orsi discuss (p. 100). Davidge (p. 102) explains recent developments in clumped water-isotope analysis, which provides more detailed information about the path of a water parcel from evaporation at the source, to precipitation on the ice sheet.

Robust age models provide the foundation to interpret the relatively high-resolution paleoclimate records from ice cores (Fig. 1b). Bouchet et al. (p. 104) showcase how Antarctic glaciological models for older ice are tuned using dating constraints from orbital parameters, the geomagnetic field, and volcanic eruptions. Fang et al. (p. 106) describe how radiocarbon in shallow Alpine ice cores can be used to resolve detailed climate records over the Holocene. Soteres et al. (p. 108) describe surface exposure dating of ^{10}Be, a cosmogenic nuclide, on Patagonian glaciers to date millennial-scale climate shifts that resemble signals seen in both Greenland and Antarctic ice cores.

Integrating ice-core data with models is crucial to reliably forecast anthropogenic global warming. Slattery and Sime (p. 110) assess the effectiveness of ice-core data in statistical tools to pinpoint the timing of abrupt changes from Greenland glacial records.

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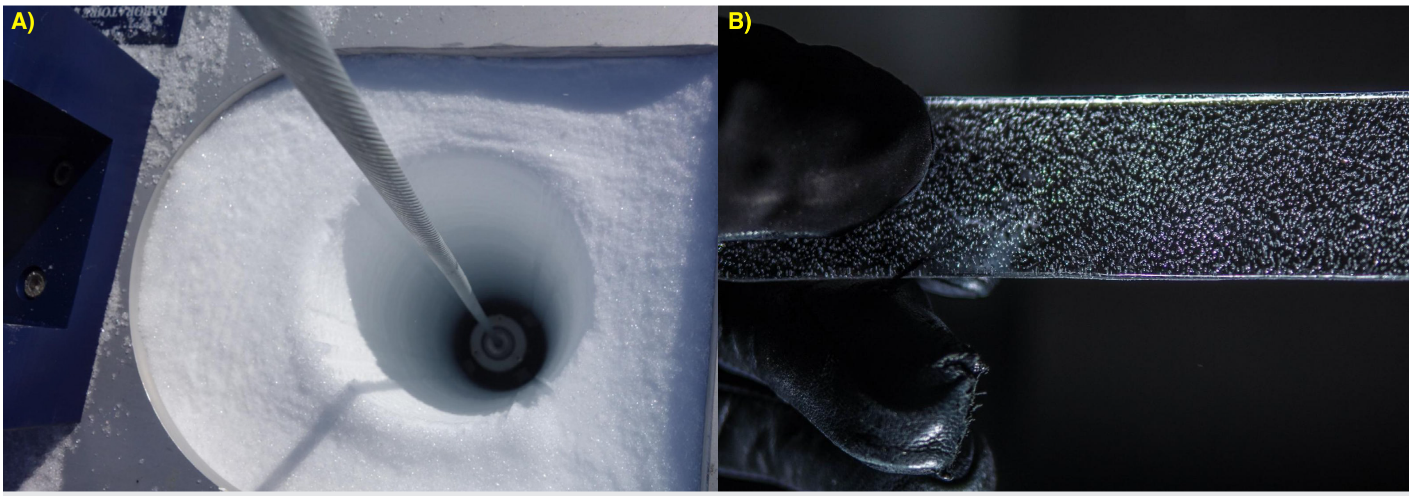

Figure 1: (A) Looking back through time down an ice-core borehole. Photo credit: LSCE, GLACCIOS. **(B)** Visible air bubbles in an ice core recovered from Talos Dome. Photo credits: A. Grisart and J-W. Yang.