Antarctic temperature change and its relevance to future ice core drilling efforts

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Despite the fascinating diversity of glaciological flow conditions in Antarctica, glaciologists generally treat Antarctic climate as monochromatic; it is common, for example, to use a single time series, such as the East Antarctic Vostok ice core record, as the driver of Antarctic climate boundary conditions for ice sheet models (e.g. Huybrechts, 2002), even when the focus of the research is West Antarctica (e.g. Steig et al., 2001; Pollard and DeConto, 2009). To some extent, this is justified the tendency of climate variability towards greater spatially uniformity on longer timescales. However, modern observations show that Antarctic climate is much more complex, and this complexity is expressed at least on the century (and perhaps much longer) timescales relevant to ice dynamics, particularly in regions of fast flow.

Recent observations of surface, near-surface, and tropospheric temperature change serve as a useful framework for understanding Antarctic climate dynamics. The Antarctic Peninsula is well known to have warmed substantially through most of the 20th century (and surface warming in this region is an important component in the recent loss of ice shelves there) (e.g. Vaughan et al., 2003). There is now abundant evidence that continental West Antarctica has also warmed significantly during at least the last 50 years, both at the surface and throughout the troposphere (Steig et al., 2009; Sherwood et al., 2008). In East Antarctica during the same time period, most regions have either changed little or have cooled. Several independent lines of evidence (both from ice cores and boreholes temperature records) indicate that both West and East Antarctica –like the Peninsula -- have warmed on average during the 20th century. While this general warming trend is probably attributable to greenhouse gas forcing, this is probably not primary from the direct radiative effect (i.e. it doesn't merely local radiative forcing changes). Instead, the response of the atmospheric circulation patterns to the pattern of sea surface warming at lower latitudes, and resulting changes in regional Antarctic circulation probably dominate. In particular, recent West Antarctic and western Antarctic Peninsula warming reflect the combination of enhanced warm air advection from the north due to a spin-up of the low pressure systems in the Amundsen and Bellingshausen seas; the influence of wind stress of the sea ice distribution tends to further enhance this warming. Changes in the vertical temperature profile over the ice sheet, due to the depletion of stratospheric ozone, also clearly plays a role (Thompson and Solomon, 2002), though in this author's view this is probably less important than popularly thought (after all, ozone changes did not become significant until the late 1970s).

Capturing the complexity of climate variability should be one of the primary goals for future ice core drilling efforts in Antarctica. It remains an open question to what extent our understanding of recent climate variability in the Antarctic applies on longer timescales. Existing Antarctic ice core records do not fully answer this question, in part because it has, to date, been too difficult to tease out the competing influences of elevation, circulation, and temperature on the various ice core climate proxies. However, it appears increasingly unlikely that differences between the Holocene records from Siple Dome, Byrd, Taylor Dome and the recently-completed Talos Dome record, on the one hand, and the records from the high East Antarctic plateau, can be explained simply with ice elevation changes. (Most of the evidence now points to an "ENSO-like" pattern of variability as the best explanation.) I suggest that additional ice cores in West Antarctica (or 'downstream' in East Antarctica – e.g. at Hercules Dome) should remain a priority, even after the WAIS Divide record is complete.

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