

Effect of Climate Cycling and Meltwater Plumbing on Ice-Sheet Grounding-Line Migration

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Ice-shelf response to climate cycling introduces hysteretic behavior in outlet glaciers, with the evolution of meltwater drainage networks enhancing this effect. The 2002 collapse of the Larsen B Ice Shelf (one of the floating extensions formed from glaciers flowing off the Antarctic Peninsula into the Weddell Sea) followed several years of shelf-thinning, accelerated flow, and ultimately the atypical warmth of the 2001-02 summer melt season with mean monthly temperatures rising to 4°C and meltwater production up three-fold to ~40 cm/yr (Shepherd et al., 2003; Rignot et al., 2004; van den Broeke, 2005; Vieli et al., 2006; van Lipzig et al., 2008). Yet, for at least the past half century, ice shelves along the margins of the Greenland Ice Sheet have been exposed to summer mean temperatures that hover in the 3-11°C range and melt rates that can exceed 250 cm/yr (Box et al., 2006; Vinther et al., 2006; Hanna et al., 2008; Joughin et al., 2008).

We suggest that this paradox can be explained by the advection of englacial meltwater channels that develop upglacier (Zwally et al., 2002; Das et al., 2008), thereby limiting meltwater ponding within crevasses and subsequent ice-shelf failure that is likely primed by surface and basal melting, years of thinning, as well as shear-margin weakening (Rott et al., 1998; Scambos et al., 2000; MacAyeal et al., 2003; Scambos et al., 2004; Vieli et al., 2007). Ultimately, the rapid loss and delayed establishment of ice-shelf buttressing of glacier flow amidst climate cycling leads to an asymmetric response in outlet glacier dynamics with implications for the future of the Larsen ice shelves as well as the hysteretic behavior of ice sheets.