# Deformation-induced melting in the margins of the West-Antarctic ice streams

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The mass balance of the West Antarctic ice sheet depends primarily on the location and flow speed of arterial drainage routes called ice streams, which represent localized zones of rapid ice flow separated by ridges of comparatively stagnant ice. One main challenge in current models of ice streams is the treatment of the shear margin, which plays an important role in the force balance. The goal of this study is to shed new light on the interplay between mechanical deformation and deformation-induced melting in ice-stream margins and explore to what degree the processes in the shear margins affect ice-stream dynamics. To compare our modeling results with observational data, we specifically address the margin of Whillans ice stream B2, commonly referred to as Dragon margin, but argue that our insights may apply to ice streams more generally.

We devise a 2D anti-plane strain model of an ice stream moving over a plastic bed in steady state. Our approximation neglects small components of non-anti-plane deformation that must accompany the marginal melting and drainage that we infer. We include horizontal and vertical advection, latent heat of melting, and surface crevassing into our model. We strive for a realistic description of the rheology of ice entailing multiple deformation mechanisms dominant at different stresses and accounting for the temperature dependence of material properties. By coupling heat and mass flow, we are able to show that a temperate zone is likely to form in the shear margin, where the heat production from lateral deformation is most intense.

Our numerical results are in excellent agreement with observational data for the transverse profile of surface velocities across Dragon margin measured by Echelmeyer et al., 1994. The numerical solution also enables us to test how the extent of the temperate zone and the amount of melt water produced depends on the assumed model parameters, in particular the latent heat of melting, the advection of cold ice into the margin, and the extent of surface crevassing. The simulations including surface crevassing also lend themselves to a comparison with the temperature data by Harrison et al., 1998. While a perfect fit to the observed temperatures cannot be expected within the confines of a steady-state model, we are able to reproduce the key features of the temperature data.

We conclude that Dragon margin and potentially the other active shear margins in West Antarctica are likely to be partially temperate as first suggested by Jacobson and Raymond (1998) and studied in more detail by Perol and Rice (see http://www.waisworkshop.org/abstracts/2011/Perol.pdf). For Dragon margin, we estimate a temperate zone of 4km width and 180m height, entailing a meltwater production of approximately 5m$^3$/yr per meter in downstream direction. The presence of meltwater in ice-stream margins might have important consequences for the dynamics of ice streams, because the yield stress of glacial till is highly dependent on water content (e.g. Tulaczyk, 1999). Meltwater could also form a channelized drainage system with important ramifications for the stress and pore-pressure distribution at the bed (Perol and Rice, submitted 2012).