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Exact solutions and the verification of numerical models for ice sheets

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Comparison of numerically computed solutions to exact (analytical) solutions, when possible, is superior to intercomparison (Huybrechts, et al., 1996; Payne et al., 2000) as a technique for verification of numerical models. At least two sources of exact time-dependent solutions exist for the shallow ice sheet approximation: similarity solutions and solutions with compensatory sources.

In the isothermal case, we derive new similarity solutions with nonzero accumulation which augment the zero accumulation similarity solution found by Halfar (1983). These similarity solutions are well-suited for verifying and measuring numerical margin tracking, numerical volume conservation, and adaptive time-stepping. We also describe exact solutions with basal sliding and compensatory accumulation. For all of these solutions, margin approximation error dominates other numerical errors and we explain why. Indeed, the shape of margins, if present, essentially determines the rate of global convergence of the numerical scheme.

In the thermocoupled case we describe exact solutions with compensatory accumulation and heat sources. These solutions allow us to explain, and develop techniques for reducing, the emergence of basal temperature “spokes” found in the radially-symmetric EISMINT thermocoupled experiments (Payne et al., 2000). Finally, we discuss improving existing benchmarks and implications for numerical ice modeling generally.

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