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Self-organization of mega-scale glacial lineations

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Mega-scale glacial lineations (MSGL) are elongate corrugations in sediment that develop under fast-flowing regions in ice sheets. Their distinctive shape and distribution contains information about ice and sediment that is essential to understand the mass imbalance of present and past glaciated areas. Here we use a high-resolution full-Stokes numerical model of coupled flow of ice and sediment to investigate the genesis and evolution of MSGL. We compare our results with field examples from the base of Rutford Ice Stream, Antarctica, and from the now-exposed beds of paleo-ice streams at Anvers Trough, West Antarctic Peninsula, Dotson-Getz Trough, Amundsen Sea, and Dubawnt Lake in the Canadian Shield. We show that the origin of MSGL could be explained by naturally occurring perturbations in the geometry or mechanical properties of the sediment. These original perturbations grow, redistribute and elongate, as the sediment is transported downstream, until they reach a steady configuration. We find that MSGL amplitude is dependent of the strength of the original perturbation; their length is related to the time elapsed from the genesis of the feature; and the lateral spacing between lineations depends mainly on the macroscopic mechanical properties of the sediment. Finally, we conclude that MSGL can be understood as a self-organized system as their geometry and distribution is determined by local interactions between individual lineations and not as a response to the global flow of ice and sediment.