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The key role of global solid-Earth processes in the onset of Northern Hemisphere glaciations

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Northern hemisphere glaciation started ∼3 My ago with Greenland leading the other northern areas. It is unknown why these extreme global climatic transitions were initiated there and why at this time. Here we show that build-up of the Greenland ice-sheet was underpinned by three major solid-Earth processes. These processes were active since at least ∼60 Ma and collectively led to conditions of sufficiently high topography and northern latitude of Greenland for glaciations to initiate at ∼3 Ma. First, a strong mantle-plume pulse, causing the North Atlantic Large Igneous Province at ∼60 Ma, regionally thinned the lithosphere, while subsequent pulses led to uplift that accelerated at around 5 Ma. Our numerical mantle flow models also suggest recent uplift caused by Iceland plume material flowing northward. Second, a ∼700 km northward movement of Greenland relative to the mantle since ∼60 Ma is featured in recent plate tectonic reconstructions. Third, a concurrent northward rotation of the entire mantle and crust toward the pole, dubbed True Polar Wander (TPW), contributed a 12° (∼1300 km) change in latitude. Our study emphasizes the role of mantle plumes, plate tectonic motions, and in particular TPW for driving long-term global climatic transitions.