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Meltwater retention within the Greenland ice sheet percolation zone: a near-binary separation between firn aquifers and impermeable ice slabs?

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The firn layer on the Greenland ice sheet (GrIS) provides pore space for storing surface meltwater and thereby modulating runoff. In the percolation zone, surface meltwater has several options: it can infiltrate the local firn pack, where it is temporarily stored in either liquid or refrozen forms, or it can run off along the surface or via englacial drainage systems. For current and future ice-sheet mass-balance assessments, it is important to quantify the proportion of the meltwater being retained in the ice sheet and the proportion reaching the ocean and thereby contributing to sea level change. In recent years, two distinct meltwater retention features have been mapped using radar data onboard NASA Operation IceBridge airplane: 1) firn aquifers were discovered that store liquid water year-round at 15-25 m depth, and 2) refrozen ice slabs of several meters thick have been found that are (close to) impermeable and therefore seal off the underlying porous firn pack. If the spatial extent of both features is combined a clear pattern emerges which suggests that a near-binary separation occurs between these two features. Here, we investigate what causes this clear separation in terms of climate and firn conditions using output of the regional climate model RACMO$_2$.3p2 and the firn model IMAU-FDM. It is found that the ratio between annual surface melt and accumulation in combination with the firn temperature at the start of summer are the principal drivers of aquifer/ice slab formation.