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Locally derived mineral dust fertilizes the glacier ice algal blooms in the 'Dark Zone' of the Greenland Ice Sheet

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The 'Dark Zone' refers to a region of low-albedo ice along the western margin of the Greenland Ice Sheet (GrIS). The Dark Zone hosts pigmented glacier ice algae that bloom on the ice surface, thereby contributing to darkening and melting of surface ice. These pigmented glacier ice algae grow in association with other impurities found on the ice surface, namely mineral dust. Mineral dust provides inorganic nutrients to the ice surface habitat in the Dark Zone. As such, constraining the abundance, composition, source, and deposition rate of mineral dust is important for understanding the role of mineral dust in glacier ice algal bloom development and thus the further development of the Dark Zone in other areas of Greenland. Here we characterize the mineralogy, geochemistry, and deposition rates of airborne mineral dust delivered to a site in the SW-margin of the Dark Zone during two field campaigns. Mineral dust delivered by both dry deposition and snowfall was composed of very fine-grained (< 1 µm diameter) silicate mineral fragments, and based on the rare Earth element (REE) signature the dust was primarily from local Greenlandic sources. Potential emission sensitivity (PES) hindcast simulations produced using the Lagrangian FLEXible PARTicle (FLEXPART) dispersion model indicated that PES values were highest over Greenland, thereby corroborating the REE geochemical results by indicating that the sampled aerosols were more likely derived from locations above or near Greenland than more distal locations. The deposited mineral dust contained low concentrations of phosphorus, present in the mineral apatite ($Ca_5[PO_4]_3[Cl/F/OH]$), confirming that atmospheric deposition of mineral dust delivers phosphorus to the Dark Zone. The delivered phosphorus is sufficient to fuel glacier ice algal growth in cell densities of 8.6×10^3 cells·mL^{-1}, which is comparable to algal blooms currently growing on the ice surface. Our findings show the importance of locally derived mineral dust in the current and future development of glacier ice algal blooms in this region, particularly as forefield ice-free regions expand in response to glacial retreat. These findings have important implications for albedo reduction and surface melting in a future warming climate.