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West Antarctic Mantle Plume Hypothesis and Basal Water Generation

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The hypothesis of a deep mantle plume that manifests Pliocene and Quaternary volcanism and present-day seismicity in West Antarctica has been speculated for more than 30 years. Recent seismic images support the plume hypothesis as the cause of Marie Byrd Land (MBL) volcanism and geophysical structure [Lloyd et al., 2015; Ramirez et al., 2016]. Mantle plumes can more that double the geothermal heat flux, q_{GHF}, above nominal continental values at their axial peak position and raise q_{GHF} in the surrounding plume head to 60 mW/m^2 or higher. Unfortunately, there is a dearth of in-situ basal ice sheet data that sample the heat flux. Consequently, we examine a realistic distribution of heat flux associated with a late-Cenozoic mantle plume in West Antarctica and explore its impact on thermal and melt conditions near the ice sheet base. The solid Earth model assumes a parameterized deep mantle plume and head. The 3-D ice flow model includes an enthalpy framework and full-Stokes stress balance. Both the putative plume location and extent are uncertain. Therefore, we perform broadly scoped experiments to characterize plume related basal conditions. The experiments show that mantle plumes have an important local impact on the ice sheet, with basal melting rates reaching several centimeters per year directly above the hotspot. The downstream active lake system of Whillans Ice Stream suggests a rift-related source of anomalous mantle heat. However, the lack of lake and stream activity in MBL suggests a relatively weak plume: one that delivers less flux by 35$\%$ below the heat flux to the crustal surface at the site of the Yellowstone hotspot [e.g., DeNosaquo et al., 2009], with peak value no higher than about 145 mW/m^2.