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Firn ice transition of dry polar firn at constant porosity

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The firn-ice transition of dry polar firn from Antarctica at Dome C (annual mean temperature: -53.9°C) and in Dronning Maud Land (-46.1°C; core B33) and from North Greenland (-30.6°C; core B26) has been investigated. Using X-ray micro computer tomography (XCT) we determined the critical density/porosity and the small scale density/porosity variations across the firn-ice transition. It is found that the firn becomes impermeable at a porosity of 0.107 although the mean temperature and snow accumulation rates at the three sites differ considerably. A porosity of 0.107 corresponds to densities of 825 kg/m3, 824 kg/m3 and 822 kg/m3, respectively (note that density is temperature dependent, while porosity is not). We suggest that the pores in dry polar firn close off at constant porosity rather than at constant density. A porosity of 0.107 may be a universal constant for the percolation threshold in polar firn. However, as natural polar firn is not an uniform stratum the transition of permeable firn to impermeable ice occurs over a wide depth range (10 to 15 m or so). There is a trend to smaller variations at colder sites. This leads us to conclude that the mean porosity at the firn-ice transition (e.g. where gravitational diffusion stops) depends primarily on stratigrafic and microstructural features and not so much on temperature. Calculations may overestimate the pore close-off depths for glacial firn when they are solely based on temperature.