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Direct measurement of densifcation rates in polar snow and the implications for altimetry

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As part of the cal/val experiments for the CryoSat radar altimeter, density profiles in the upper 10–14 m of snow have been measured along a 500 km traverse across the Greenland Ice Sheet, using a neutron scattering technique. Repeat measurements, over periods ranging from a few days to 5 years allow strainrates and densification rates to be determined as a function of depth. We show that, as expected, the strainrate decreases as the ratio of pore space to ice content decreases. Very large strain rates are observed in the surface layer of snow over summer periods. However, for multi-year snow, once the effect of porosity has been removed, the remaining mean response is constant with depth, that is the effect of increasing overburden pressure is counteracted by increasing strength of the material. The mean strainrate for multi-year snow at a given site is related to the mean annual accumulation rate and mean annual temperature by an expression consistent with the Herron and Langway equation(Herron and Langway, 1980) for first-stage densification. However, there are fluctuations in strainrate associated with the annual layering which indicate that fine and coarse-grained snow have differing strengths. We show that the temperature-dependent process equations proposed by Alley (1987) and Arthern et al. (2010) do not hold, and suggest an alternative relation based on the temperature-history of the snow. Finally we calculate the effect of our observed short-term fluctuations in compaction and accumulation on the elevation ofthe snow surface and discuss the contribution of densification to uncertainty in satellite measurements of elevation trends.

References

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