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The Cryosphere Discussions

Interactive comment on "Investigating the dynamics of bulk snow density in dry and moist conditions using a one-dimensional model" *by* C. De Michele et al.

R. L. H. Essery

Richard.Essery@ed.ac.uk

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De Michele et al. present a method for predicting the bulk density of snow on the ground from measurements of precipitation and air temperature. SWE observations are required for calibration of the model, but it performs well in subsequent validation for the two sites at which it has been calibrated.

The model consists of three differential equations: mass balance equations for the solid and liquid masses in the snow and a prognostic equation for changes in snow density due to compaction and the addition of fresh snow. The density equation, Equation (9) in this paper, or variants of it have been used in many energy-balance snow models dating back more than 30 years (I recently reviewed how such models predict snow density and how they use density in parametrizations of other snow properties; see http://dx.doi.org/10.1016/j.advwatres.2012.07.013). The novelty here seems to be that the mass balance is predicted by temperature index methods (which are also widely used in hydrological applications) with less demanding data requirements. The authors should give a clearer statement of what they think the applications of this model could be; estimation of snow mass for water resources from snow depth, which is easier to measure than mass of snow on the ground or solid precipitation, is a possible application, but this is not how the model has been set up or tested.

The model is described in sufficient detail that it should be straightforward for a reader to code and apply the model for themselves. One piece of missing information is the details of the "temperature filter". Is this a smoothing of the temperature data? How is it applied, and what is its influence?

I think that the maths could be simplified and clarified a bit. It should be made clear that the M variables are not mass, as stated, but mass per unit area, with units kg m^{-2}. The V variables can then be seen to be redundant because they are actually volumes per unit area, i.e. heights. It is not clear to me how h and h_s differ; they are shown as the same in figure 1, and the text gives $h = h_s + < h_w - -nh_s >$ but the Macaulay bracket term is always zero because the liquid water volume cannot exceed the pore volume of the snow. Bulk snowpack temperature T_s is required for the parametrization of compactive viscosity in Equation (7), and the method by which it is obtained is described at the beginning of Section 2.2; this could be stated more explicitly. As I understand it, snow temperature is assumed to be equal to air temperature at the snow surface and increases with increasing depth in the snow at rate a_T up to a maximum of 0°C. Working out the average gives $T_s = -T_A^2/(2a_T h)$ if $T_A < 0°$C. The given value of a_T = 0.033 °C mm^{-1} looks comparable to the slope of lines in Figure A3 of Kondo and Yamazaki (1990), but I don't see the actual number quoted in that paper; how was it determined?

I do not think that Bartelt and Lehning (2002) really say that ‘modelling efforts have been concentrated principally on dry snowpack rather than on wet snow’. There are many models that assume dry snow, but snow hydrology is an essential component of any model that claims to have a physical basis.

The calibrated model in figure 2 consistently underestimates SWE from about mid-February 2008 onwards. Could this not be further improved by a decrease in the degree-hour factor. Models also often use a threshold temperature other than 0°C for distinguishing between snow and rain. This could reduce the overestimation of SWE accumulation for the calibration period in figure 3.

The labels on figures 2 and 3 are rather small in the discussion paper, and the choice of axis range does not help in some cases; it is not necessary to allow densities up to 1400 kg m^{-3} and a 100°C temperature range. Plotting precipitation on a reversed axis is a common trick in hydrology to show rainfall and runoff on the same graph, but it is not necessary here.

Note that the references with author names beginning with J are out of order.

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