Dear Reviewer,

thank you very much for the encouraging feedback and the suggestions for improvements. Below please find your comments in black with our inline replies in red.

Sincerely, on behalf of the authors

Henning Löwe

Schurholt et al. show that coupled equations for heat transport, vapour diffusion and ice mass conservation in snow permit wave solutions in density. The linear stability analysis is nice work that, together with numerical solutions of the nonlinear equations, demonstrates that these are true mathematical solutions and not numerical artefacts. The setting is limited to be somewhat short of a full snow thermodynamics model, and the question of how mm-scale waves in solutions of the continuous equations relate to a bicontinuous material with mm-scale structure remains open.

Specific comments by line number:

5

Is FEniCS widely enough known to name in an abstract without explanation?

In fact, no. Changed.

16

No physically based snow model would neglect vapour transport between snow and the atmosphere in its mass balance. What is commonly neglected is internal vapour transport in the snow (which does not directly influence overall mass balance) and vapour exchange with the soil.

We agree that this may be misleading. Specification “internal” added.

107

What value is used for Beta? Calonne et al (2014) describes its measurement as a challenge.

The value for beta has been added in the table and this difficulty has been pointed out again.

Table 1

Units of vapour pressure are incorrect, and this should be vapour density. Incorrect units for D0. Use scientific notation in place of 2e-5.

This is supposed to be *density*. Changed.

172 (and hereafter)

Set vector u in boldface italic.

Changed.

185

Superscripts n and n+1 should be inside the parentheses on the lhs of equation 9.

Corrected.

219

could note H = 1 m

Noted.

220

The description in Calonne et al. (2014) is much easier to follow than equation (13): the surface temperature decreases linearly from 273K at t=0 to 263K after 5 hours and then remains constant.

Why is T at z = 1 m only slightly below 270K after 10 hours in Figure 1?

There was an error in the figure legend. It is not the solution after 10h that is compared here. After 10h the solution is a stationary (linear) temperature profile for all cases which is meaningless to compare. Corrected.

Figure 1 caption

Transient temperature decrease at the boundary, not an increase

Corrected.

Condensation rate would be a more intuitive profile to show in place of “rhs energy eq.”.

Changed.

229

Hansen and Fosllien (2015) envisaged this as a snowpack containing an ice crust. The solid ice at the base of the snowpack was imposed to prevent vapour entering from below.

Description adapted.

244

No comparison is made with tomography experiments, so why choose such a small snow depth?

The goal of this scenario is to explore the behavior of the PDE system when the density changes on small length scales. As outlined in the discussion, each layer transition in a snowpack constitutes such a situation. Another example might be thin crusts as studied in the given reference by X-ray tomography. And since the solution far away from the crust is well behaved (and “boring”), it is sufficient to work with a small depth. Description adapted.

250

Incorrect units of sigma^2.

Corrected.

252

300K snow in Figure 3 is passed without comment. A full snow model (and, indeed, nature) would not permit this.

Agreed and comment added.

255

Advection of the ice crust by sublimation and deposition was already apparent in Scenario 2.

Formulation changed.

283

Is there a missing ice density in equation 24?

Yes. Corrected.

300

Deff *is* linear in ice volume fraction for the Calonne model.

Yes but k_eff is not constant so this is still different from the Calonne model.

305

The oscillations at the boundary in Figures 3 and 4 are clearly numerical artefacts and are not the ones of interest in the following. They are reminiscent of instabilities in an unstable numerical solution of the linear advection equation and could be controlled (as actually shown in 6.1).

Agreed. But we are not classifying the type of oscillations here, we are just saying that we care about all oscillations in further detail in the next section.

310

What were ne and dt in Figure 4? What is the time in Figure 5? Why are the oscillations on the sublimating side of the crust not apparent in Figures 3 and 4?

Number of elements and time step, notation adapted to match the text. The oscillations are not visible in Fig 3 because it shows the solution at an earlier physical time. For Figure 4 we believe that the instability is actually removed when making the approximations that lead to the pure advection equation (23). However, the behavior of the latter is difficult to analyze analytically.

Figure 5

Units of dt should be given in the legends.

Corrected.

444

Why is this a “nasty coincidence”?

This is rephrased now. But it remains nasty, since both type of oscillations (numerical and physical) appear almost hand in hand while adding complexity to the innocent question “how does vapor transport change the mass balance in a snowpack”.

550

Vapour density is required

Corrected.

553

Error in exponent for a0 value. All of these parameters have units.

Corrected.

Minor corrections:

25

“have been used for a long time”

Corrected.

31

“revisited the problem”

Corrected.

49

Richards equation

Corrected.

61

“design”

Corrected.

179

“implementation in”

Corrected.

346

“PDE system (26)”

Corrected.

383

“density modulation in the layer-transition region”

Corrected.

407

“a stand-alone solver in the open source software”

Corrected.

534

“comes into play”
Corrected.

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