Review egusphere-2024-297

A quasi-one-dimensional ice mélange flow model based on continuum descriptions of granular materials

1 General comments

This paper derives a novel continuum-mechanical model for ice melange dynamics. In recent years, ice melange has been recognized to buttress glacier flow and affect calving fluxes, among other things, which makes it important to include in ice sheet models. However, its properties resemble those of a granular medium, which makes its representation in conventional ice sheet models challenging. This study provides an important step towards including these effects.

My comments below focus mostly on clarifying the derivation of the model, which I think is the most important part of the paper.

2 Specific comments

a) Line 55: Before jumping right into the derivation of the model, it would be very helpful for the readers if the authors briefly summarized the assumptions upon which the model is going to be based and where the main differences to the traditional SSA model are going to be. Providing these pointers early will help the reader to understand what is going on later.

b) I would also suggest a sketch of the geometry. Especially later when the integrations are performed, readers are expected to be familiar with the vertical integration of momentum balance equations and which boundary conditions are applied, which is probably not true for everyone.

c) The model is stated incompletely: please write out which boundary conditions are assumed, that is, where is the surface of the melange, where is the base, what is the inflow boundary condition, what is the outflow, what are the stresses/velocities there, this sort of thing.

d) Line 59: "Tectonic stress" – I hadn't come across this term before. In the continuum-mechanical literature usually deviatoric stresses are used which are defined in a similar fashion — also in your equation (5) below. Could you add a short note here explaining how these stresses differ from deviatoric stresses and why you use them?

e) Generally, there is really no need to introduce strain rates and velocities until after equation (7), which is a more natural place to start talking about how stresses are related to strain rates. Consider re-ordering for clarity.

f) Line 64: "inertial number": can you provide the definition here? Most readers will probably not be familiar with this number

g) Line 66: please typeset $\partial\sigma_{ij}/\partial x_j = \rho g_{\text{eff}}\delta_{iz}$ as a separate equation – this makes it easier for people scanning the text without reading every word to follow the maths

h) Line 71: Integrating from where to where (boundary conditions!)?

i) Line 59 & equation (3): R_{ij} seem to refer to both vertically-averaged and non-vertically averaged stresses. Maybe change the latter to r_{ij}?

j) g' is a slightly confusing choice for the granular fluidity, as g is also standard gravity and g' is sometimes used for $(1 - \rho_i/\rho_w)g$. Could you use a different letter?

k) equation (17): is it possible for the denominator to go to zero or become negative? Are you applying a regularization here when solving numerically?

l) line 153: this is a good point to mention that you consider your analysis in a moving reference frame that is fixed at the glacier terminus

m) line 164-165: where exactly is the regularization applied?

n) line 169: "The value of μ_w is related" $\rightarrow$ "The value of μ_w in (19) is related"

o) from the text it wasn't clear to me whether μ_w in equation (19) must come from solution of the y–component of the fluidity equation which makes solution of (19) more onerous?

p) Line 284-296: I couldn't quite follow this argument, and I don't think the results in questions are shown in the paper. Maybe add a sketch to explain your argument?

q) Line 297-301: Point out somewhere here that melting enters into the model through $\dot{B}$ in equation (25)

r) Line 298-300: "[...] melange extent is sensitive to melt due to its indirect effect on lateral shear stresses": would that be the second term on the right hand side of equation (19) which depends on H^2 (please add reference in manuscript)? If not, how does this dependence come about?