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A well-balanced entropy scheme for a shallow water type system describing two-phase debris flows

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In the context of modeling two-phase debris flows involving grains and fluid, some shallow water systems arise with internal variables.
Our work focus on such a shallow water system with two internal variables and a topography b which adds a nonconservative term. \\

For numerical purposes, it is desirable to deal with a system where the mathematical entropy (the physical energy of the system) is convex with respect to the chosen conservative variables. Then at the numerical level, we can look for a scheme satisfying a semi-discrete entropy inequality. It also preserves the steady state at rest, so-called "well-balanced".

Our system is written as

\begin{equation}
\partial_t h+\nabla_x(hv)=0,
%\label{eq:h}
\end{equation}
\begin{equation}
\partial_t\bigl(hv\bigr)+\nabla_x\Bigl(h v\otimes v \Bigr)+g_c\nabla_x\Bigl(r
\frac{h^2}{2}\Bigr)+g_c h\nabla_x(b+\tilde b)=T,
%\label{eq:hv}
\end{equation}
\begin{equation}
\partial_t\rho+v\cdot\nabla_x\rho=\Phi_1,
%\label{eq:rho}
\end{equation}
\begin{equation}
\partial_t r +v\cdot\nabla_x r = \Phi_2,
%\label{eq:r}
\end{equation}
with the energy
\begin{equation}
E = h\frac{|v|^2}{2}+g_ch(b+\tilde b)
+g_cr\frac{h^2}{2}.
%\label{entropy}
\end{equation}

The physical unknowns of the system are the total mass h, the velocity v, the density of the mixture layer ρ and a variable r depending on the proportion of fluid between the layers.
Sources terms Φ_1, Φ_2 and T contains multivalued friction and dilatancy effects. \\

Writing the system with conservative variables for which the energy is convex, we derive a well-balanced scheme satisfying a semi-discrete entropy inequality.
A numerical test case of injection of some mixture and fluid into a box will be discussed to illustrate the importance of the dilatancy effect.

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