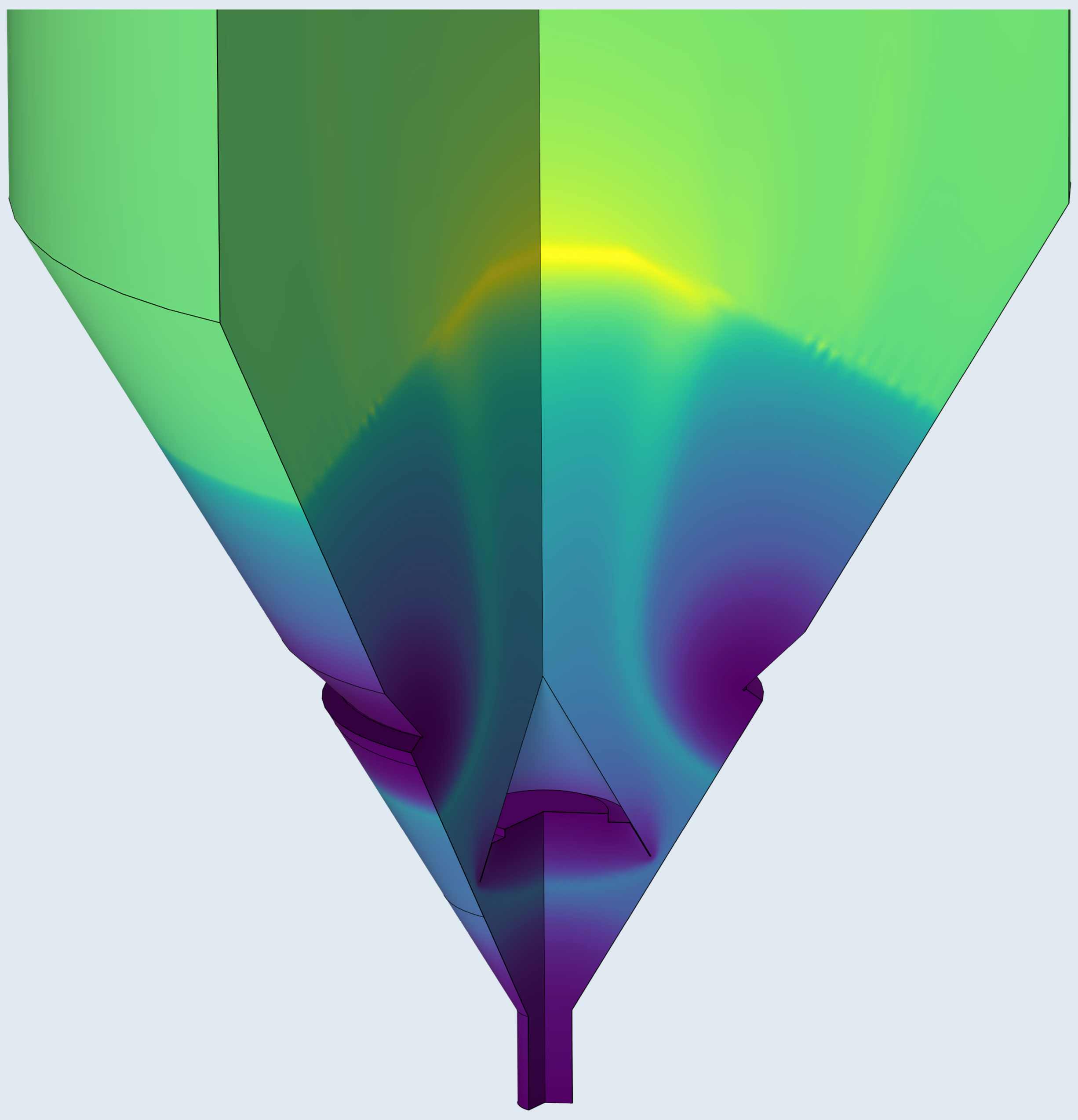

Degassing of PP Pellets in a Silo

A 2D axi model was built to calculate the evolution of concentrations over time in the silo while it is gradually filled with polypropylene pellets.

Goal: the model was used to specify the minimum flow of purge gas at various inlets, such that the maximum C9 concentration anywhere is always far below the lower explosion limit (LEL).

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Methodology

A variable f is defined: f = 1 in the pellet bed, f = 0 elsewhere (free flow), consistent with the gradual filling of the silo.

In the pellet bed, the flow is solved for using the Ergun equation with an approximation for low flow velocities.

For the C9 concentration a convection-diffusion equation is solved, taking the flow velocity in the advective term from the Ergun equation. The C9 source term is treated as outlined in the grey box.

Because the C9 degassing is faster at higher temperature, and the purge gas is hotter than the initial pellet temperature, we need to keep track of temperature in the pellet bed. This is done with a two-temperature model.

Main Result

In figure 1, one can see the maximum concentrations are well below the lower explosion limit (LEL) for the chosen inlet flows.

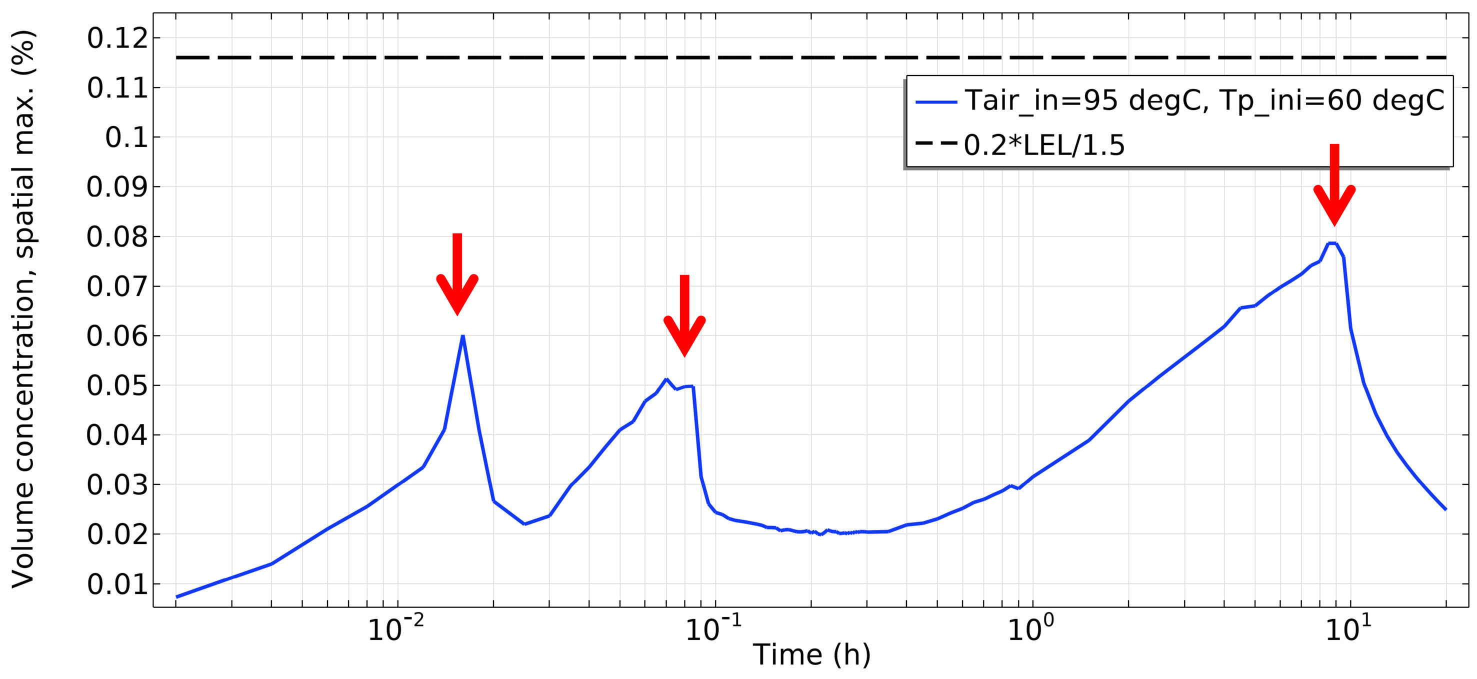

Figure 1. Spatial maximum of the C9 concentration vs time during filling of the silo.

The C9 Source Term

For the source term in the convection-diffusion problem, i.e. the C9 production rate, we use the following approach.

We define the variable A (units of area) as:

$$A = \int_0^t fD(T)dt$$

where D is the diffusivity, which depends on temperature, and thus on time in this problem.

The average concentration in a pellet is a function of A: $c_{av} = c_{av}(A)$.

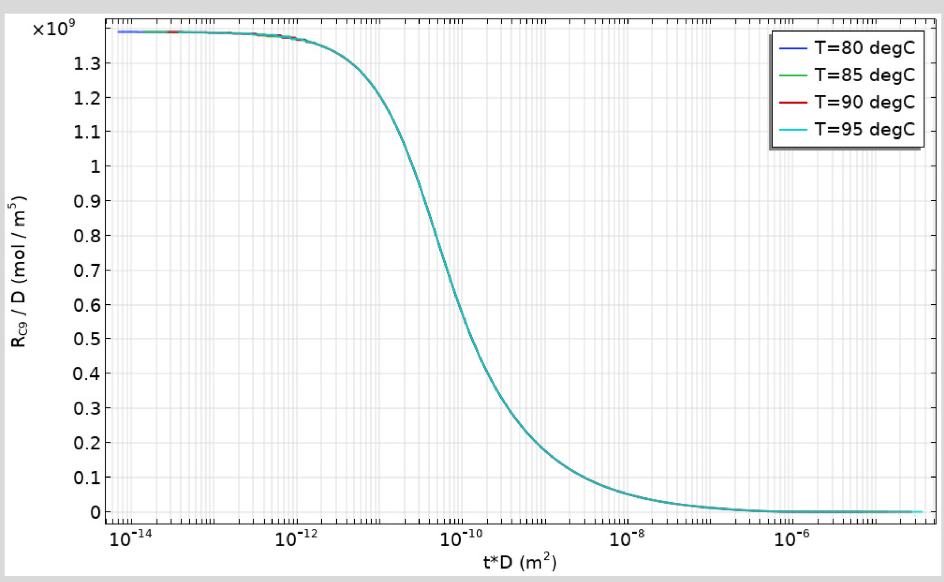

Figure 3. $R_{C9}/D(T)$ vs A at different temperatures. The curves overlap, showing that it is a 'univariate' function, depending only on A.

The C9 production rate is then proportional to the time derivative of this:

$$R_{C9} \propto -\frac{dc_{av}}{dt} \propto -\frac{dc_{av}}{dA} D(T)$$

This means R_{C9}/D is a function of the argument A only, which is very convenient for modelling. This function is determined based on an analytical equation for c_{av} that is too tedious to state here. The argument A is calculated via a domain ODE.

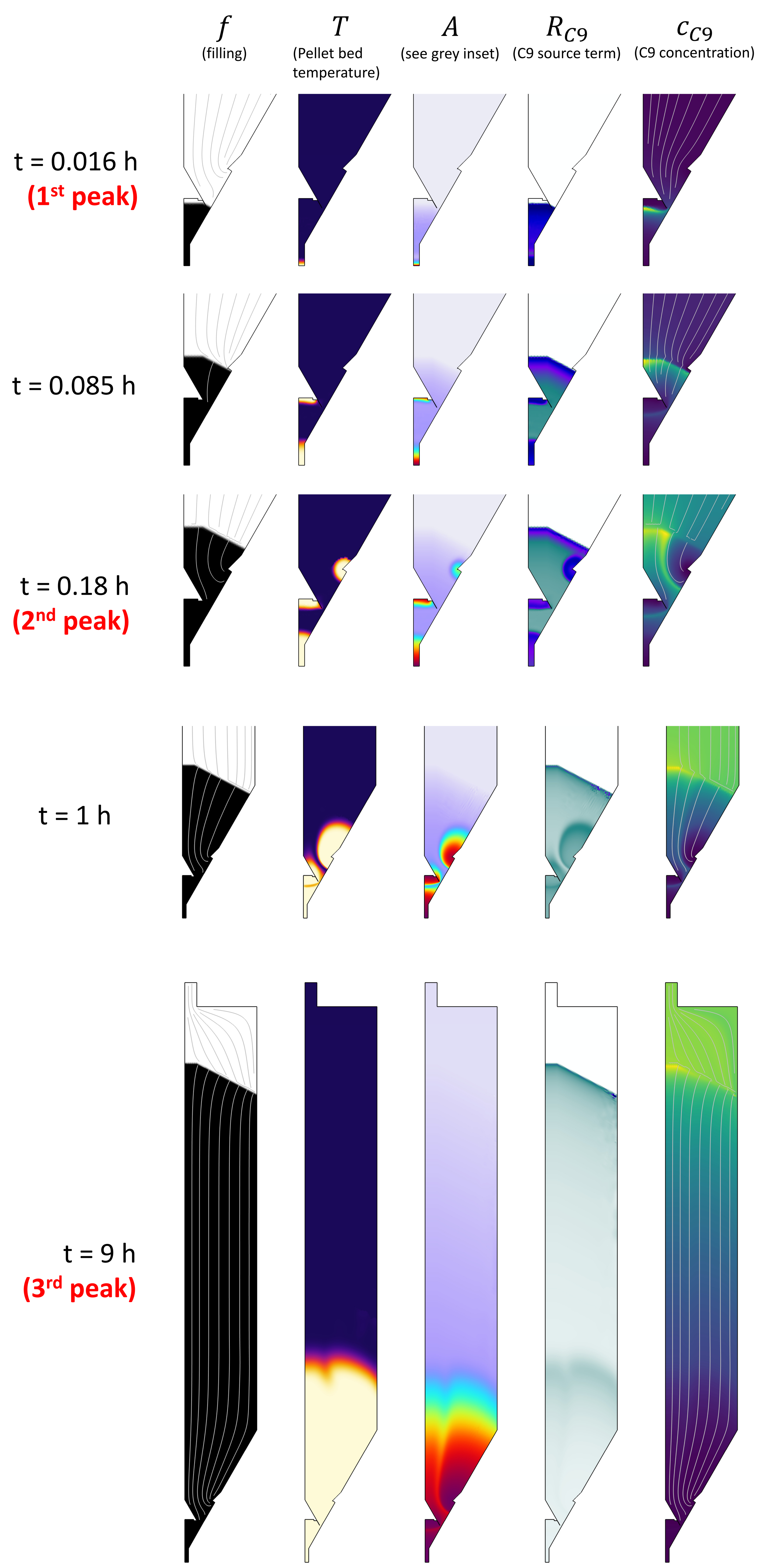

Figure 2. Quantities in the silo plotted at various times during filling.

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