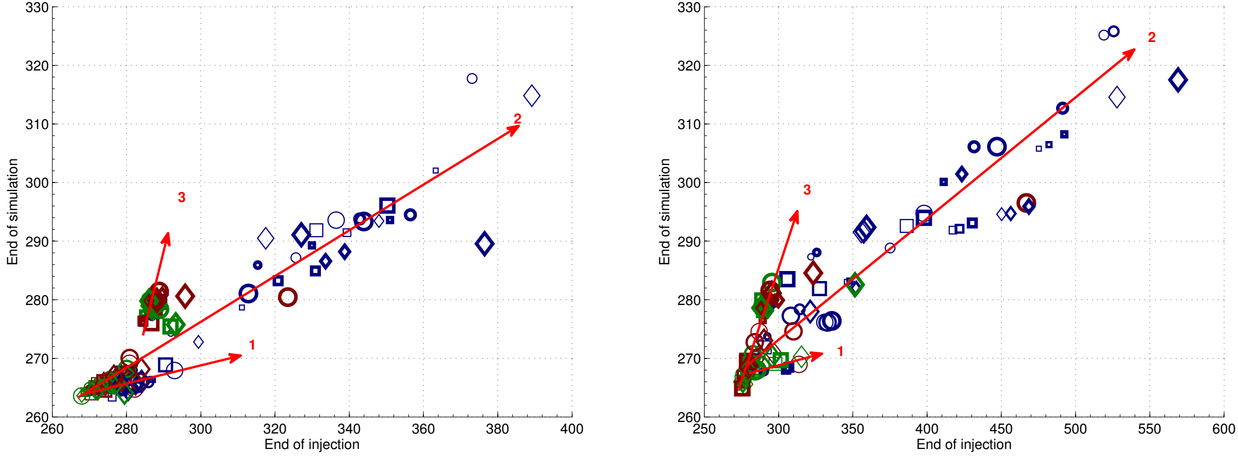

Figure 4: Cross-plot of average aquifer pressure at the end of simulation versus at the end of injection for linear (left) and quadratic (right) relative permeabilities.

storage scenarios, however, the segregation of supercritical CO_2 and brine will typically take place in the rock with high permeability. This is the basis for the popularity of so-called vertical-equilibrium models [42] for investigating CO_2 sequestration. The effective relative permeability after segregation has occurred is linear if capillary effects are small, and if nonlinear relative permeabilities are used, large errors will occur in cells in which segregation should have occurred and the saturation is low, as demonstrated in [36]. Sensitivity to vertical grid resolution is also observed by Wei and Saaf [52]. In the following, we will therefore primarily use linear relative permeabilities, even though this choice is not necessarily representative on the small scale. Introducing linear relative permeabilities can be viewed as using the pseudo-relative permeabilities that are least influenced by the vertical grid resolution and best represent the flow of the system for large grid blocks. In addition, using linear relative permeabilities not only simplifies and speeds up the flow simulations, but also accentuates and accelerates the flow effects we study. For completeness, however, we also report results using nonlinear relative permeabilities.

3 Basic Flow Responses

In this section we will give a qualitative discussion of how some basic flow responses like the wave speeds of the plume migration, average aquifer pressure, mobile and residually trapped volumes, and plume sizes are affected by variations in the geological parameters.

3.1 Pressure responses

The average aquifer pressure in general shows a sharp jump at the start of injection and a declining trend during injection and plume migration caused by pressure release through the open boundaries. (Specifying different boundary conditions would have resulted in different pressure trends). Figure 4 shows cross-plots of the average aquifer pressure at the end of injection and end of simulation for our two different choices of relative permeability functions. In both plots, one can recognize three different trends which have been indicated by three straight lines. The first trend, which has the gentlest slope, represents cases with large pressure variation during injection and small range of pressure variation during the migration phase after the end of injection. In these cases, the heterogeneity of the medium forms channels toward the open boundaries through which the injection pressure is released, resulting in low aquifer pressure at the end of simulation. The second trend, represents cases in which the heterogeneity affects injection, gravity segregation, and flow through open boundaries. In particular, we observe that most cases that have high injection pressure correspond to a low aggradation angle, for which low vertical permeability forces the injected CO_2 plume to move relatively slow in the lowest, poor-quality layers before migrating up toward the cap-rock, see Figure 5. This increases the pressure in the domain during injection and keeps a higher pressure gradient to the open boundaries. In the third trend, which includes scenarios with closed faults, the heterogeneity makes chambers and