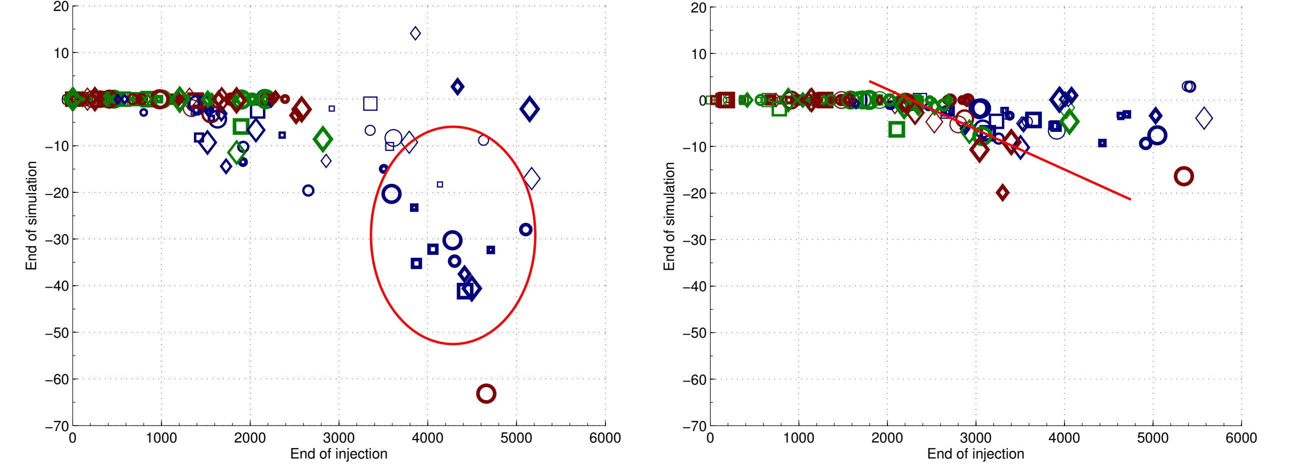

Figure 6: Cross-plot of CO_2 flux out over the down-dip boundary for linear (left) and quadratic (right) relative permeabilities. Positive values represent outward fluxes and negative values represent inward fluxes.

angle stand out from the rest. In these cases, the injected plume is almost entirely confined to the bottom of the model because of poor vertical communication (see Figures 5 and 7). Hence, a large portion of the injected volume will be forced out of the domain in the down-dip direction. After the end of injection, gravity forces will gradually cause some of these lost volumes to move up-dip again and reenter the domain. We notice that cases with closed faults (shown is the red circle in the left plot of Figure 6) show a relatively higher return flux for the linear relative permeability function. With nonlinear relative permeability function, some of the cases follow a linear trend (shown by the red line in the right-hand plot), in which the return flux is proportional to the outward flux.

3.2.2 Total mobile/residual CO_2

Residual trapping occurs when the CO_2 saturation is below the residual saturation value of 0.2. Although the residually trapped CO_2 is free to move in a molecular sense on the microscale, the corresponding bulk volume is considered immobile on the macro scale. To reduce the risk of leakage, it is therefore important to obtain an efficient volumetric sweep that will maximize the residual volumes and minimize the mobile volumes. Herein, we will define residually trapped volumes as volumes in which the CO_2 saturation is below the residual value of 0.2. Notice that with this definition, all mobile volumes (in which the saturation exceeds 0.2) will contain a residual portion of CO_2 that is not free to escape. This portion will eventually become residually trapped if the saturation of the mobile CO_2 decreases to the residual value.

Figure 9 shows cross-plots of the total residual volume at the end of injection versus the residual volume at the end of simulation. Drainage is the dominant flow process during injection. When injection ceases, the plume migration turns into a imbibition-dominated process which increases the residual trapping of CO_2. With linear relative permeability, the imbibition process takes place relatively fast and the residual volume increases significantly in the post-injection phase. Once again, low-aggradation cases form notable exceptions that have small amounts of residual trapping. The reason is primarily that significant volumes have been lost over the down-dip boundary, and secondarily that the (vertical) sweep is limited because the CO_2 plume is confined to the lower layers of the reservoir during most of the simulation time.

With quadratic relative permeabilities, the predicted migration process is significantly slower and many cases have almost the same residual volume at the end of injection and end of simulation. As already discussed on page 7, the prediction of the gravity segregation of CO_2 and brine is strongly affected by vertical grid resolution for nonlinear relative permeabilities and may severely under-predict segregation in low-saturation regions. On the other hand, the curvature of the relative permeability function does not have a considerable influence on the flow path (compare the streamline paths in Figure 10 for a selected case). Compared with the results in the left right plot of Figure 9, we therefore ultimately expect a significant increase in residual trapping before the plume settles; this prognos-