WCTI Interview with Dr. Ye Zhang

Question: How does your research contribute to the development of accurate and efficient models for CO_2 storage?

Answer: We have tried to tackle this problem from two main angles.

1) We use forward subsurface models to perform an upscaling procedure. We put a lot if information such as complicated distribution of subsurface permeability into these forward models, but then we start loosing this detail. We try to understand how we can build computationally efficient and sufficiently accurate models at low resolution. We want these lower resolution models to capture the average flow and transport behavior of the system. Instead of a flow rate at a single point location, we want to predict flow rate over some larger reservoir volume – an averaging volume. If we can predict the average flow rate, then we can predict the average CO_2 fluxes instead of getting a point-by-point variation of the CO_2 fluxes, which would demand a huge amount of data. Therefore, model optimization is our ultimate study objective. How much detail do we put into our model with which we can still make sufficiently reliable predictions? We say reliable, which means that the model will give you a range of predictions, and hopefully this range of predictions captures the true behavior in the complex reservoir.

2) The second angle is that we conduct inverse modeling with which we try to infer parameters of the reservoir related to the measurements. The inverse method is approaching the same problem from a reverse angle as that of the forward models. It will also help us answer the parameter resolution question. Our long-term goal is to meet in the middle [with both inverse and upscaling methods] where we can get the right parameters at the right resolution to answer the right questions. We have made a lot of progress on forward upscaling. We also have made progress with the inverse models, but we are still developing the inverse method.

Descriptive information can be very helpful in building our models. We don't want to make too many simplifying assumptions; therefore we want to bring descriptive information into the model. But, some of the details may not be important for predicting subsurface fluid flow and solute transport. We don't completely understand what details are really important. This is also part of our studies. We want to create optimum models that inform us of the best data to collect. What is the necessary data? How can we find the right location, the right quantity, the right type of characterization data with which we can build these optimal models? There is a feedback between the model and the data.

Question: What data are necessary to put in the models and what data are not?

Answer: I can tell you about what data are necessary for the models, but I do not yet know what data may not be necessary. We need to drill into the subsurface so we can directly sample the reservoir properties as well as the reservoir state variables (e.g., the pressure and flow rate). Without boreholes, we don't have direct fluid flow information and we cannot even calibrate our models using inverse methods.

Question: Do you need porosity, permeability, and mineralogy?

Answer: Mineralogy will help distinguish subsurface flow units. Different mineralogy of different lithofacies may have different average porosity and permeability characteristics. They can also have small-scale variability. Can we ignore small-scale permeability and come out with an effective porosity and effective permeability to represent the unresolved geologic variability in the model? This is part of the upscaling question.

We are currently doing a research project where we explicitly model fluid-rock reactions. We have a mineral assemblage in our aquifer and caprock, and we inject CO_2 and see how CO_2 reacts with the brine and creates aqueous species that react with the rock matrix (dissolve and precipitate). These reactions change the rock porosity and permeability. We are currently funded by a DOE grant to look at the effect of heterogeneity and transient porosity/permeability as well as reactions. That is an extremely hard problem called multi-phase reactive transport simulation.

Question: Multi-phase reactive transport simulation seems very relevant for monitoring a CO_2 reservoir or CO_2-EOR field. Is this true?

Answer: We haven't worked on monitoring involving complex longer-term reactions yet because we need to first learn how to forward model it accurately. So, that is a long-term goal. If our models are really good, then they can predict 10,000 years in the future. It all boils down to the question of can we build really accurate models? What we are studying is fundamental. We try to assess the accuracy of the models, and then we hope we can use these models to make accurate predictions.

Question: Is validation a focus of the research right now?

Answer: Validation would be a future research goal – it is extremely difficult to validate models of a real reservoir because of the imperfection and uncertainty in modeling – we need to first understand model behavior via upscaling and inverse analysis, then we apply our insights to building models of a synthetic reservoir whose parameters and processes are completely known (e.g., via laboratory experiments), and finally insights gained from both computation and laboratory research can be applied to real reservoirs.

Question: Is there a difference in how much the tailored models you are developing cost versus a typical model that is being used right now?

Answer: I don't know how the resources and manpower used to collect the data and build the model translates to dollars. Computation time must also figure into the cost. We have not worked on the economic aspect of the problem.

Question: Why is it important for you to use the Supercomputer at the University of Wyoming? Can your modeling research be done on computers with less computing power?

Answer: Right now we are doing upscaling, which requires that we build a very detailed model. A very detailed model uses millions of grid cells, which translates to lots of equations. Those equations require a lot of memory and computational power to solve, which means most PC computers are incapable. Eventually we will develop models that are sufficiently accurate but with much fewer grid cells and equations that they can be solved on a PC. This computational optimization – using PC instead of supercomputers – is also part of our research question.