Progress Report
Agency: DOE NETL
Project title: Integrating Natural Gas Hydrates in the Global Carbon Cycle
Agency Award Number: DE-NT0006558

Executive Summary

We have been working on two fronts in the development of the two-dimensional model of sediment accumulation and hydrate formation. The first is the transport of methane in the gas phase through the sediment column. Improving the gas flux behavior of the model required reformulating the vertical coordinate system of the entire code, which has been done. We have established a collaborative relationship with Ruben Juanes at MIT, who is doing DOE-funded work on bubble transport through the sediment column. Finally, we are working on improving the mechanistic realism of the sediment transport and deposition in the model.

Approach

The previous formulation of the code was based on a vertical coordinate system that strictly followed the depositional layers, and as such created a new grid point in the vertical, beginning as a zero-thickness layer at the sea floor, periodically in time, as new sediment accumulates on top of old. This formulation led to numerical difficulty in that the flux of methane to the sea floor was going through a top layer which periodically has zero thickness, right after a new layer is created. The vertical coordinate system has been reformulated to spawn new layers periodically at bedrock, where the numerical disturbance is less critical. The solid material advects through the computational grid through the course of the simulation, at a flux rate intended to preserve the correspondence of the numerical layers with the depositional age. By relaxing the strict correspondence between sediment age and sedimentary layers, adding this vertical advective flux, we have also been able to reformulate the scheme to eliminate the occurrence of zero-thickness computational layers. The top layer, next to the sediment surface, is maintained at a uniform thickness of 10 meters throughout the simulation. The new layers, spawning at bedrock, are initially taken to be 2 meters thick, by borrowing material from the layer above it. This formulation enhances the numerical stability of the code in general and the bubble fluxes in particular.

We have met with DOE-funded researcher Ruben Juanes at MIT and discussed a collaborative effort to enhance the realism of the bubble flux parameterization, on which Dr. Juanes is working in a very detailed, microscopically mechanistic way. A preliminary bubble flux formulation has been developed in which the effective viscosity through which the gas is traveling scales with the bubble volume, approaching gas viscosity when the bubble fraction is high. Dr. Juanes' group and ours will interact by sharing results of the model using various gas flow parameterizations, iteratively selecting a scheme which produces bubble distributions that mimic observational data.

The second front is the scheme by which sediment is deposited in the model, resulting in the production of clinoform depositional structures as observed. The model currently uses an ad-hoc scheme which has the sole virtue of producing a realistic-looking outcome, but it (1) doesn't sort the sediment by grain size and (2) cannot reproduce the sensitivity of real sediment deposition to changes in sea level, characteristics of sediment input, etc. We have obtained and compiled the detailed SEDFLUX model from Syvitski and Hutton, and are reading papers about other sediment transport and deposition models, with the aim of developing a parameterization of sediment deposition based on sediment transport and sinking behavior in the water column and subsequent resuspension.

Conclusion

The model thus reformulated will be better able to predict the distribution of methane hydrate and bubbles in the sediment column, and therefore also the response of the methane cycle in the sediment column to anthropogenic climate change.