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Integrating Natural Gas Hydrates in the Global Carbon Cycle

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Executive Summary

The passive margin manuscript has been rewritten to reflect the new results, but one final tweak to the model scenario appears to be necessary: I am adding the Wallmann kinetics formulation for the inhibition of the degradation rate with increasing concentration of metabolites CH_4 and CO_2. The change is indicated by the isotopic composition of dissolved inorganic carbon, which shows that methanogenesis is limited to a shallower depth range in the sediment column than what the model is simulating based on organic carbon age and temperature as sole controlling variables. The change to the code was easy but the production runs will take about 10 days. I anticipate submitting the passive margin paper to EPSL in the fall.

The active margin scenario has also progressed considerably including the drafting of an initial manuscript. The scenario encompasses the entire Juan de Fuca plate, to the spreading center 400 km away, so that the availability of carbon in the deep sediment column is determined by sedimentation in the model domain, rather than an incoming sediment column as boundary condition. The model spins up into a beautiful stationary solution that is quite realistic, but it does not produce massive amount of methane hydrate. These scenarios are much faster to spin up than the passive margin simulations.

The Arctic simulations are also proceeding from Patrick McGuire. We anticipate having these simulations ready for analysis in the fall. The interesting thing to note will be the inhibition of gas migration imposed by the permafrost, leading to much higher overpressures than we get in either of the first two scenarios.

A Gulf of Mexico scenario will begin with an expansion of the model domain and a ~10x increase in the flux of sedimenting material, putting a wider width range of the domain into the range of thermogenic methane production. The Gulf, too, is subject to overpressures much higher than what we got in the passive margin case. The overpressures are controlled entirely by the fate of bubbles; currently they are considered mobile everywhere.

Animations from the current code level 2.5, from the passive margin scenario can be from http://geosci.uchicago.edu/~archer/spongebob_passive/, and from the active margin scenario at http://geosci.uchicago.edu/~archer/spongebob_active/

Approach

1. Results from the passive and active margin scenarios were shown at the chemical oceanography Gordon Conference in August, two weeks ago, from which developed the need to add Wallmann's metabolite inhibition factor to the biogenic methane production rate. Methane concentrations are measured in many DSDP/ODP cores but they often show decreasing values with great depth in the sediment column, which could mean that methane gas is lost during sediment handling. But the carbon isotopic composition of DIC *retains a memory of cumulative methane chemistry that is preserved. Comparison with data from Sivan and Schrag shows that biogenic methane is being produced too deeply in the sediment column, because our $\delta^{13}C$ DIC numbers are more positive than observed (we get +30 while the observations reach +10 or so). Also, the isotopic composition becomes constant with depth below a few hundred meters.*

2. The active margin scenario has been the main point of code development, as the bookkeeping for sediment redeposition has been finally debugged. Sediment resuspension takes all sediment size classes, but then they can size fractionate as they redeposit. POC concentrations are also fractionated by the size fractionation, by the assumption that the POC concentration scales with the surface area of a size class of sediment, not its volume. In test scenarios where a sediment column composed of all size classes gets eroded, there is a strong POC size fractionation effect. In the full active margin simulation, however, the stuff that erodes tends to be large grain size sediment that was originally deposited in shallow water, and most of it falls out in the next gridpoint. So there is not much impact of the POC size fractionation mechanism on the full active margin scenario.

3. The Arctic scenario, which is nearly complete, relies on the permafrost module and time-variable sea levels (Task 5). For the Arctic scenario, we have chosen to model the formation of a passive margin in the region of the Beaufort Sea. We are driving the formation of the Arctic passive margin with estimates of the air temperature, seafloor temperature, sea level, and POC, as these four quantities have evolved since the beginning of the Cretaceous period (when the Beaufort Sea started to form) until the present. The time evolution of the POC includes two oceanic anoxic events in the Cretaceous period, when the POC was quite a bit higher than normal. With permafrost forming in the cold, exposed sediments (when the sea level is low), we see a thick layer of methane hydrate forming underneath the icy permafrost.

Future

Revised passive scenario margin runs are going. The active margin scenario runs may be good enough to submit, unless one of us can think of a way that the real world may be making more methane than the model is. The Arctic scenarios are in the stage of finding the model resolution required to achieve stationarity in the efflux of CH_4 and doing the production runs. The Gulf of Mexico scenario begins now with the expansion of domain size and sediment rain as described above.

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