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Simple Ocean Carbon Cycle Models tell different Stories about the Ocean's Glacial CO_2 Chemistry

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Idealized ocean carbon cycle models are essential in identifying processes and mechanisms crucial to glacial/interglacial changes in atmospheric CO_2. But how comparable are the properties of different simple models and how uniform are the responses among them to the same forcing? I have analyzed the differences between a three-box model, a seven-box model, and an advection-diffusion model (ADM) regarding high/low-latitude sensitivity, carbonate compensation, and responses to standard forcings such as temperature, biological pump, high-latitude mixing, overturning, and rain ratio. The results among the models are quite different from each other. The ADM's high-latitude sensitivity is smaller than in box models but larger than in most general circulation models (GCMs). Its biological pump strength and sensitivity to low-latitude forcing are larger than in box models and resemble those of GCMs. I demonstrate that these features can be attributed to the ADM's vertical diffusion scheme and a different effect of deep water ventilation via the high-latitude box on average ocean chemistry. If the high- (low-) latitude sensitivity of the real ocean turns out to be smaller (larger) than in box models, then ADMs may be useful in understanding glacial pCO_2 cycles, while box models may not. The responses of the three models to calcite compensation are also very different, leading to divergent model pCO_2 predictions and in one case even to pCO_2 changes of opposite sign!