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Towards a better understanding of coupling strategies by use of a prototypical 1D Ocean-Ice interaction

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In earth system models (ESM) a number of sub-components, like atmosphere, ocean, terrestial and cryospheric systems are coupled with each other. Most often these sub-systems communicate with each other by exchanging boundary values or fluxes at their interfaces. In many cases the communication intervals are relatively large due to the different time scales of the corresponding sub-components or simply due to computational cost considerations.

A rigorous mathematical analysis of the sensitivity of such coupling strategies on the overall system state (the solution of the system) is very difficult and to the author's knowledge has not yet been performed. In order to gain quantitative information on the effect of different coupling strategies, in particular coupling time scales and quantities, and convergence properties - a prototypical one-dimensional model of heat transfer between ice and ocean has been employed to test different coupling strategies. This „toy problem" can be solved semi-analytically for both phases simultaneously such that a system solution is available. Loose coupling by exchange of boundary values on long time intervals, tight coupling by overlap regions and iterative adjustments as well as higher order coupling by exchanging boundary values with higher order moments are compared to the system solution and show significant differences. As a preliminary conclusion, our study suggests to investigate currently used coupling strategies with more rigor and in particular for long term paleo-climate simulations.