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Conservation and consistency in the finite element ocean model SLIM on moving unstructured meshes

L. White (1,2), V. Legat (1), E. Deleersnijder (2,1)

(1) Université catholique de Louvain, Centre for Systems Engineering and Applied Mechanics, Belgium, (2) Université catholique de Louvain, G. Lemaitre Institute of Astronomy and Geophysics, Belgium (lwhite@mema.ucl.ac.be)

Water volume and tracer mass conservation are key properties of ocean general circulation models designed to run over very long timescales. In addition, the following property is critical. Setting a tracer concentration to a uniform value throughout the closed domain and letting the free surface undulate, the same tracer concentration must be recovered at any later time (if there is no tracer source). This property of consistency, together with monotonicity, will ensure that no spurious tracer extrema occur. In the latest version of SLIM (Second-generation Louvain-la-Neuve Ice-ocean Model, http://www.climate.be), both these properties are achieved. We present a finite element spatial discretization of the hydrostatic primitive equations on moving unstructured meshes that ensures consistent conservation of any tracer. The elements chosen for the primitive variables allow for consistently conserving any tracer and do not support any kind of spurious oscillations. No stabilization is required. The moving computational domain allows for accommodating the free-surface motions by expressing the equations in the Arbitrary Eulerian-Lagrangian (ALE) formulation. The model is shown to adequately respond to freshwater input as a natural boundary condition. A realistic test case involving the flow around a shallow-water island is first presented and we also apply the model to a baroclinic test case. A few experiments where consistency breaks down are carried out and the consequences of it investigated.