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Fully automatic adjoints: a robust and efficient mechanism for generating adjoint ocean models

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The problem of generating and maintaining adjoint models is sufficiently difficult that typically only the most advanced and well-resourced community ocean models achieve it. There are two current technologies which each suffer from their own limitations. Algorithmic differentiation, also called automatic differentiation, is employed by models such as the MITGCM [2] and the Alfred Wegener Institute model FESOM [3]. This technique is very difficult to apply to existing code, and requires a major initial investment to prepare the code for automatic adjoint generation. AD tools may also have difficulty with code employing modern software constructs such as derived data types.

An alternative is to formulate the adjoint differential equation and to discretise this separately. This approach, known as the continuous adjoint and employed in ROMS [4], has the disadvantage that two different model code bases must be maintained and manually kept synchronised as the model develops. The discretisation of the continuous adjoint is not automatically consistent with that of the forward model, producing an additional source of error.

The alternative presented here is to formulate the flow model in the high level language UFL (Unified Form Language) and to automatically generate the model using the software of the FEniCS project. In this approach it is the high level code specification which is differentiated, a task very similar to the formulation of the continuous adjoint [5]. However since the forward and adjoint models are generated automatically, the difficulty of maintaining them vanishes and the software engineering process is therefore robust. The scheduling and execution of the adjoint model, including the application of an appropriate checkpointing strategy is managed by libadjoint [1]. In contrast to the conventional algorithmic differentiation description of a model as a series of primitive mathematical operations, libadjoint employs a new abstraction of the simulation process as a sequence of discrete equations which are assembled and solved. It is the coupling of the respective abstractions employed by libadjoint and the FEniCS project which produces the adjoint model automatically, without further intervention from the model developer.

This presentation will demonstrate this new technology through linear and non-linear shallow water test cases. The exceptionally simple model syntax will be highlighted and the correctness of the resulting adjoint simulations will be demonstrated using rigorous convergence tests.

References

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