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Modelling geophysical flows with nonoscillatory forward-in-time methods

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The advance of massively parallel computing in the nineteen nineties and beyond encouraged finer grid intervals in numerical weather-prediction models. This has improved resolution of weather systems and enhanced the accuracy of forecasts, while setting the trend for development of unified all-scale Earth-System models. This lecture illustrates this trend with a review of a versatile nonoscillatory forward-in-time (NFT) approach proven effective in simulations of a broad range of geophysical flows and, especially, in simulations of atmospheric flows from small-scale dynamics to global circulations and climate. The outlined approach exploits the synergy of the MPDATA methods for the simulation of fluid flows based on the sign-preserving properties of upstream differencing and optional finite-difference or finite-volume discretizations of spatial differential operators comprising PDEs of geophysical fluid dynamics. The lecture consolidates the concepts leading to a family of generalized nonhydrostatic NFT flow solvers that include soundproof PDEs of incompressible Boussinesq, anelastic and pseudo-incompressible systems, common in large-eddy simulation of small-and meso-scale dynamics, as well as all-scale compressible Euler equations. Such a framework naturally extends predictive skills of large-eddy simulation to the global atmosphere and oceans, providing a bottom-up alternative to the reverse approach pursued in the weather-prediction models. Theoretical considerations are substantiated by calculations attesting to the versatility and efficacy of the NFT approach. Some prospective developments are also discussed.

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