Towards convection-resolving numerical weather prediction at ECMWF

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Over the next decade, many aspects of ECMWF's Integrated Forecasting System (IFS) may need to change in light of higher-resolution global forecasts called for by ECMWF's long-term strategy. The dynamical core lies at the heart of the model infrastructure. It numerically solves the fundamental governing equations, which take the form of physical conservation laws describing the resolved atmospheric dynamics. The dynamical core is coupled to parametrizations of subgrid-scale physical atmospheric processes and to models of other Earth system components. The current IFS dynamical core relies on the spectral-transform method to solve the hydrostatic primitive equations. ECMWF is continuing to develop this dynamical core, which also includes a nonhydrostatic option, to make it as computationally efficient as possible. Additionally, ECMWF develops novel nonhydrostatic dynamical core formulations with local spatial discretisations which are complementary to the spectral-transform technique in terms of computational patterns and parallel communication.

The Finite-Volume Module of the IFS (IFS-FVM) employs finite-volume semi-implicit integration methods for atmospheric dynamics at planetary- to micro-scales. The integration scheme combines conservative flux-form Eulerian advection based on the non-oscillatory MPDATA scheme with three-dimensional, fully implicit time-stepping for all acoustic, buoyant and rotational modes. The IFS-FVM adds many novel features to IFS, and these may become particularly important with respect to future high-performance computing and forecasts at very high resolution. The solution quality of IFS-FVM has been verified for relevant test cases at intermediate complexity against the established spectral-transform IFS dynamical core, and to other models in the context of DCMIP. Moreover, computational efficiency of IFS-FVM versus the spectral-transform IFS on current supercomputers and for today's operational resolutions appears promising for the future. In 2019, the first real weather re-forecasts were performed with IFS-FVM coupled to the IFS physical parametrization package. Further refinement and comprehensive experimentation will be conducted in 2020-2021.

Kühnlein, C., W. Deconinck, R. Klein, S. Malardel, Z.P. Piotrowski, P.K. Smolarkiewicz, J. Szmelter, N.P. Wedi, 2018: FVM 1.0: a nonhydrostatic finite-volume dynamical core formulation for the IFS. Geosci. Model. Dev., 12, 651-676, https://doi.org/10.5194/gmd-12-651-2019, 2019