Exploring Non-Hydrostatic Effects in ECMWF's IFS: Stability, Accuracy, and Forecast Skill at Kilometer-Scale Resolutions

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Abstract

The Integrated Forecast System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) incorporates both hydrostatic and non-hydrostatic options. While the hydrostatic configuration is currently used for all operational forecasts, the non-hydrostatic option remains primarily a research tool. However, stability issues encountered at kilometer-scale resolutions have thus far limited comprehensive testing and direct comparison between the two approaches.

Recent advancements have significantly improved the stability of the IFS non-hydrostatic dynamical core, facilitating reliable and accurate simulations at fine spatial resolutions. This study presents these enhancements and evaluates their effectiveness through multiple test cases, with grid spacings as fine as 1.4 km. The performance of the improved non-hydrostatic model is assessed against its hydrostatic counterpart, revealing that non-hydrostatic effects become more pronounced at resolutions approaching 1 km. However, their influence on forecast accuracy at 3–5 km resolutions remains relatively minor, mainly affecting the lower stratosphere over the Tibetan Plateau during mid-winter.

Keywords: NWP, IFS, hydrostatic vs nonhydrostatic models, stability of time stepping, vertical discretisation

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