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INCREASING HORIZONTAL RESOLUTION IN GLOBAL NWP AND CLIMATE SIMULATIONS – ILLUSION OR PANACEA ?

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The steady path of doubling the global horizontal resolution approximately every 8 years in numerical weather prediction (NWP) at the European Centre for Medium-Range Forecasts (ECMWF) may be substantially altered with emerging novel computing architectures. It coincides with the need to appropriately address and determine forecast uncertainty with increasing resolution; in particular, when convective-scale motions start to be resolved. There are different sources of uncertainty to be considered: uncertainty around the best estimate of the initial state, uncertainty due to imperfect model assumptions, uncertainty due to the choices made for particular numerical algorithms, and due to the numerical truncation as well as round-off errors. An informed decision on the modeling strategy for harnessing exascale, massively parallel computing power thus also requires a deeper understanding of the sensitivity to uncertainty — for each part of the model. Ultimately, this implies the need for a deeper understanding of multi-scale interactions in the atmosphere and their numerical realisation in ultra-high resolution NWP and climate simulations. With such information formal accuracy may be traded for enhanced numerical efficiency, while maintaining or even improving the meteorological forecast performance. Here we explore the importance of the ratio used for the horizontal resolution in gridpoint space versus wavenumbers in spectral space, which is motivated by the finding that the effective resolution of global NWP models compared to observations is only about 6-8 gridlengths. Thus spectrally filtering (and removing aliasing of higher order terms) at relatively lower truncation but with the same, or increased number of gridpoints, is equivalent to filtering the smallest (poorly resolved) gridlengths. In the spirit of large-eddy simulations, there appears then scope for implicitly or explicitly modeling the interaction of well-resolved and unresolved scales.

So far, subgrid-scale stresses are neglected in global NWP other than in the vertical direction via phenomenological parametrization. As part of the ongoing effort to combine the virtues of unstructured mesh technology within a spectral model framework, MPDATA based ILES properties may perhaps be used for modeling more effectively the interaction of subgrid-scale and resolved motions. The reported MPDATA scheme operates on dual meshes with an efficient parallel edge-based data structure and a non-staggered arrangement of flow dependent variables. The unstructured mesh is bespokely built around the vertices of the reduced Gaussian grid employed in ECMWF's — spectral transform based — Integrated Forecast System (IFS), so that a hybrid spectral/gridpoint model is achieved. Immediate benefits of an MPDATA option in IFS are i) a conservative transport of passive tracers, and ii) the computation of horizontal derivatives with compact mesh stencils, opening avenues for improved physical parametrizations and local turbulence closures. Furthermore, the locality of the parallel communication pattern used in MPDATA has desirable parallel scaling properties, becoming increasingly important on future computer architectures.