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EDITORIAL

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Preface: multiple scales in fluid dynamics and meteorology

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Atmospheric flows and many fluid flows of engineering interest feature a multitude of characteristic length and time scales and associated scale-dependent processes. In theoretical investigations, quantitative meteorological forecasts, or in engineering design, the ensuing complexity is often handled by employing techniques of computational fluid dynamics. Yet, in a typical application, even the most powerful computer available today would not allow us to resolve all the scales of a flow in detail. At the same time, we are mostly not interested in all these details anyway, but rather in a flow's larger-scale features and effects. As a consequence, in practical flow simulations, we have to introduce a minimal spatiotemporal resolution as represented, e.g., by the size of a computational grid cell and by the minimal allowed time step. The effects of processes not resolved in space and time on the space-time grid are then approximately represented by "closure schemes" or "parameterizations".

For decades, practitioners in numerical weather forecasting proceeded as follows in this context: A target grid resolution was decided upon, depending on the expected available compute power. Then, subgrid scale process parameterizations were developed and implemented in an up-to-date flow solver (dynamical core) operating on the chosen grid. Finally, any free constants in the parameterizations were tuned for the entire simulation system to achieve the highest-possible weather prediction skill scores. It was common sense that any sizeable increase in grid resolution would necessarily have to be followed up by a re-tuning or even a partial rewrite of the subgrid scale process parameterizations. The situation is similar for engineering turbulent flow simulation using "large eddy simulation" approaches.

In recent years, however, meteorologists as well as fluids engineers have become aware of the potential benefits of dynamically adaptive computational grids, and major meteorological centers and engineering research groups are incorporating grid adaptivity in their next-generation dynamical cores. Dynamically adaptive grids come with a caveat, though, as regards subgrid scale parameterizations. Because the spatiotemporal resolution that would be found in a simulation at any given point in space and time is not known in advance in an adaptive simulation, it is no longer possible to "tune" one's parameterizations to perfection and then perform all production runs with the optimal parameter setting. Rather, one now needs *adaptive parameterizations* as well, which dynamically move particular processes from the realm of "grid resolved features" to the realm of the subgrid scales, and do so smoothly in the intermediate regimes, where the relevant processes are only partially resolved at the current resolution. Similarly, intelligent refinement and coarsening criteria are needed that place high resolution where it produces the largest benefit given some overall goal for the simulation. Needless to say that the development of such adaptive parameterizations requires to account for the subtle competition of (partially resolved) subgridscale processes with truncation errors of the underlying computational flow solver and that this necessitates balanced cooperations between physical/mathematical modellers and numerical analysts.

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The described scenario provided the scientific motivation for the German Priority Research Program 1276 “MetStröm” (2007–2013) and for its International Conference on “Multiples Scales in Fluid Dynamics and Meteorology” held in Berlin in the summer of 2011. Each contributor to the conference was invited to submit a full-length article to *Theoretical and Computational Fluid Dynamics*, and the result are the present three issues which carry the same title as the 2011 conference.

The papers of the first issue address specific questions of the influence of numerical truncation errors in small-scale flow simulations, covering processes of pure fluid turbulence (Gassner and Beck), cloud–turbulence interactions (Dietze et al., Bordás et al.), and two idealized turbulence models (Lignell et al., Dolaptchiev et al.).

The contributions to the second issue study multiscale interactions in meteorologically relevant regimes with less emphasis on issues of numerical truncation. The volume includes internal wave–turbulence interactions (Remmler and Hickel), the turbulence structure in forest canopies (Schröttle and Dörnbrack), clouds, turbulence, and entrainment (Kumar et al., Schmidt et al.), and three papers on inertial waves and quasi-two-dimensional turbulence (Borcia and Harlander, Seelig et al., von Larcher et al.).

The third issue collects contributions that address larger-scale processes from meteorological meso-scales ($\sim$100 km) to planetary scales from different methodological angles. The volume includes a quantitative comparison of regional meteorological dynamical cores based on very different numerical techniques (Brdar et al.), and four papers analysing and simulating multiscale wave interaction phenomena in the equatorial belt (Khouider and Ying, Kacimi and Khouider, Stechmann et al., Frenkel et al.).

The papers collected in this special issue represent a solid body of research work that should be of very high value in the context of our original motivation: the development of adaptive parameterizations in dynamically grid-adaptive computational systems.

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