Global Environmental Multiscale model with a new terrain-following vertical coordinate based on height

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The dynamical core of the Global Environmental Multiscale (GEM) model, used operationally by Environment and Climate Change Canada (ECCC) for numerical weather prediction (NWP), employs a log-hydrostratic-pressure-type terrain-following vertical coordinate. A major advantage of such a coordinate is that it permits the use of a fast direct solver. However, recent tests have revealed that the direct solver loses scalability for very large number of processor cores. This limitation therefore necessitates the development of more scalable iterative solvers for future generation of massively parallel computer systems. A height-based vertical coordinate is considered to be more amenable to such iterative solvers as the metric terms originating from the vertical coordinate transformation appear explicitly in the discretized elliptic boundary value problem.

Strong numerical instability over steep orography (slopes > 45°) is another challenging problem pertaining to the existing GEM dynamical core. Inaccurate estimation of the horizontal pressure gradient in the terrain-following coordinate is considered to be the trigger for this instability. Improving approximations of horizontal gradients by modifying the horizontal differencing stencils is expected to improve the instability problem. Again, a height-type coordinate, being time-invariant, is considered to be more appropriate for such modifications.

The aforementioned limitations of the pressure-type vertical coordinate system have motivated the development of a new height-based dynamical core for the GEM model at ECCC. The new dynamical core has been evaluated against the existing model for two dimensional theoretical benchmark cases as well as for regional and global forecasts, and is found to be equivalent in terms of accuracy. Preliminary test results also indicate that the new vertical coordinate leads to improved numerical stability over steep orography. The formulation of the new dynamical core, the adopted strategy for dynamics-physics coupling and the results pertaining to the different numerical experiments for model evaluation will be presented at the workshop.