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Petascale Opportunities and Challenges for NASA's Weather and Climate Modeling

Abstract: The arrival of petascale computing presents a number of novel opportunities and associated challenges for NASA's Modeling and Assimilation Program (MAP). Such opportunities include spatial resolutions that enable cloud-permitting global modeling, improved data assimilation via four-dimensional variational analysis (4D-VAR), coupled atmospheric chemistry, and generally enhanced physical complexity. To scale efficiently on the anticipated number of processors, a new implementation of the finite-volume dynamical core on the cubed-sphere grid has been integrated to replace the traditional latitude-longitude grid. This eliminates various scaling and time-step constraints associated with singularities at the spherical poles. The 4D-Var poses challenges due to the weak scalability of the linearized model exercised on a coarse grid many times within the 'inner-loop' of the assimilation cycle, in addition to the tremendous memory required for storing the intermediate trajectory. Such an immense memory requirement typically mandates temporary storage on disk which exacerbates the already serious I/O concerns at the petascale. Although climate models are generally run at coarser resolutions, scalability has historically been addressed by the need to run multiple realizations of the model. With current technology trends, a greater emphasis must be placed on improving the strong scalability of our models.