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The development of global GRAPES 4DVAR

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Abstract: Four-dimensional variation data assimilation (4DVAR) has given a great contribution to the improvement of NWP system over the past twenty years. Therefore, our strategy is to develop an operational global 4D-Var system from the outset. The aim at the paper is to introduce the development of the global GRAPES four-dimensional variation data assimilation (4DVAR) using incremental analysis schemes and to presents results of a comparison between 4DVAR using 6-hour assimilation window and simplified physics during the minimization with three-dimensional variation data assimilation (3DVAR).

The dynamical cores of the tangent-linear and adjoint models are developed directly based on the non-hydrostatic forecast model. In addition, the standard correctness checks have been performed. As well as the development adjoint codes, most of our work is focused on improving the computational efficiency since the bulk of the computational cost of 4D-Var is in the integration of the tangent-linear and adjoint models. In terms of tangent-linear model, the wall-clock time is reduced to about 1.2 times as much as one of nonlinear model through the optimizing of the software framework. The significant computational cost savings on adjoint model result from the removing the redundant recompilations of model trajectories. It is encouraging that the wall-clock time of adjoint model is less than 1.5 times as much as one of nonlinear model. The current difficulty is that the numerical scheme used within the linear model is based on strategically on the numeric of the corresponding nonlinear model. Further computational acceleration should be expected from the improvement on nonlinear numerical algorithm.

A series of linearized physical parameterization schemes has been developed to improve the representation of perturbed fields in the linear model. It consists of horizontal and vertical diffusion, sub-grid scale orographic gravity wave drag, large-scale condensation and cumulus convection schemes. We also found the straightforward linearization based on the nonlinear physical scheme might lead to significant growing of spurious unstable perturbations. It is essential to simplify the linear physics with respect to the non-linear schemes. The improvement on the perturbed fields in the tangent-linear model is visible with the linear physics included, especially at the low level.

GRAPES variation data assimilation system adopts the incremental approach. The work is ongoing to develop a pre-operational 4DVAR suite with 0.25° outer loop resolution and multiple outer-loops configurations. One 4DVAR analysis using 6-hour assimilation windows can be finished within 40-minutes when using the available conventional and satellite data. In summary, it was found that the analysis over the northern, southern hemispheres, tropical region and East Asian area of GRAPES 4DVAR performed better than GRAPES 3DVAR for one month experiments. Moreover, the forecast results show that northern and southern extra-tropical scores for GRAPES 4DVAR are already better than GRAPES 3DVAR, but the tropical performance needs further investigations. Therefore, the subsequent main improvements will aim to enhance its computational efficiency and accuracy in 2017. The global GRAPES 4DVAR is planned for operation in 2018.