Report on the Development of Regional GSI-based WRF 4DVAR

ACAPS 2010 SoW Task 3.1.b

Xin Zhang and Xiang-Yu Huang

MMM, National Center for Atmospheric Research, Boulder, CO 80305

Acknowledgements

We would like to thank **Dr. Ricardo Todling** *for his help to kick off the project and* **Dr. Thomas Auligne, Dr. Junmei Ban, Mrs. Xiaoyan Zhang, Mr. Feng Gao** *for their help and encouragement.*

ABSTRACT

The regional GSI-based WRF 4D-Var has been developed via the coupling of the latest Boulder repository GSI code with the newly developed WRF tangent linear and adjoint model (WRFPLUSV3). To compile GSI-based WRF 4D-Var, the WRFPLUSV3 replaces WRF as the required pre-built package, the pre-built WRFPLUSV3 not only provides WRF IO interfaces to GSI , but also it is served as a library to provide the interfaces of nonlinear WRF model, tangent linear and adjoint model, as well as utilities to deal with basic states, perturbation and adjoint forcing. The single observation experiment confirms the basic function of this 4D-Var system, which is able to produce the flow-dependent increment with minimization including tangent linear and adjoint models. 15-day CONUS domain partial cycling real-data experiments are conducted to further validate this 4DVAR system and all verification scores confirm the performance of the regional GSI-based 4D-Var system over regional GSI system.

1. Upgrades of WRF tangent linear and adjoint model

To couple the WRF tangent linear and adjoint model (WRFPLUS) with GSI, the subroutine interfaces for WRF tangent linear and adjoint have been constructed. Some other subroutines, such as save/read basic states, perturbations and adjoint forcing are also coded. Furthermore, the WRFPLUS has been upgraded to the latest WRF repository and the adjoint check can achieve 15-16 digital identical. Now, we are working on the parallelization of WRFPLUS.

2. Coupling GSI with WRFPLUS

A module named wrf_pertmod.F90, has been coded to sever as the coupler or hub between GSI and WRFPLUS. It is the only new add-on file in source codes. It includes the interfaces to call WRF, WRF_TL and WRF_AD separately. It also includes the subroutines conducting the transfer of state variables between GSI space and WRF space and their adjoint.

At this moment, the GSI-based WRF 4DVAR can run with 1-processor parallel run due to the undergoing WRFPLUS parallelization. We have tested the system on IBM with XLF compiler and Linux with PGI compiler.

3. Single Observation test

4DVAR approach has the capability to implicitly evolve the static background error statistics. Single observation is the best way to demonstrate the property of 4DVAR. The analysis time is 2000-01-25-00 and the 4DVAR time window is 6 hours. A single 500mb temperature at (32.5,-72, marked as a red star) is assimilated at the end of the time window on 2000-01-25-06. Figure 1 shows the hourly increments between the 6-hour control run (from first guess) and analysis run (from 4DVAR analysis).

The maximum of analysis increment at 0h is on the upstream and it evolved with time follow the wind stream. Eventually, at the end of time window, the maximum arrives the observation location and the pattern of the increment has the flow dependent property.

4. 3-day real case

A 3-day CONUS domain, see Figure 2, are setup to run experiments to verify the performance of the GSI-based WRF 4DVAR system. The domain size is 47x32x28L, horizontal resolution is 135km; The Initial conditions and boundary conditions at every 6h are prepared from 2007-09-10-00 to 2007-09-13-00 and the initial conditions are the 12h forecast from NCEP FNL analysis; the NCEP GDAS prepbufr data will be used in assimilation.

We ran 3 experiments to compare the performance of the data assimilation.

The first experiment is the CONTROL run without data assimilation, 48h forecast are made four times per day. The second experiment (3DVAR)is the 48h forecast from 3DVAR analysis four times per day. The third experiment (4DVAR) is the 48h forecast from 4DVAR analysis four times per day. Then, all the 48h forecasts are verified again the NCAR archived LITTLE_R format observation.

Figure 3 to Figure 11 show the profile RMSE from 0h to 48h forecast. At 0h, the 3DVAR gets the smallest profile RMSE overall as 3DVAR uses more observations in 0h that 4DVAR; At 6h, 4DVAR is the best, it is reasonable because 4DVAR uses the observations at 6h; In the subsequent forecast, 4DVAR experiment wins the verification and confirm our expectation. In the future, we will conduct higher resolution and longer period runs to further confirm the benefit of the 4DVAR.

List of Figures

1 Hourly increment evolution from 0h to 6h 7
2 domain configuration 8
3 Profile RMSE at 0h 9
4 Profile RMSE at 6h 10
5 Profile RMSE at 12h 11
6 Profile RMSE at 18h 12
7 Profile RMSE at 24h 13
8 Profile RMSE at 30h 14
9 Profile RMSE at 36h 15
10 Profile RMSE at 42h 16
11 Profile RMSE at 48h 17

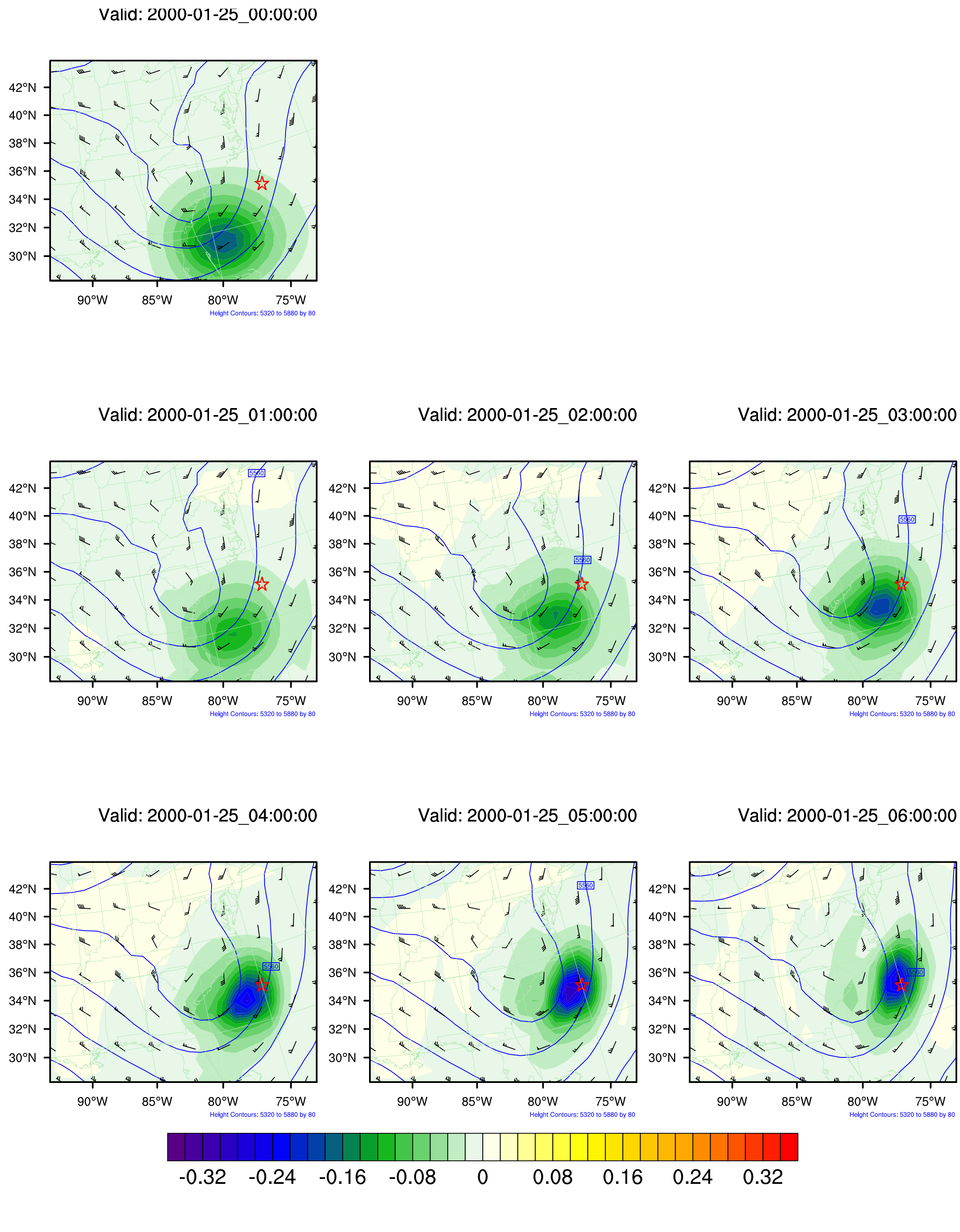

Fig. 1. Hourly increment evolution from 0h to 6h

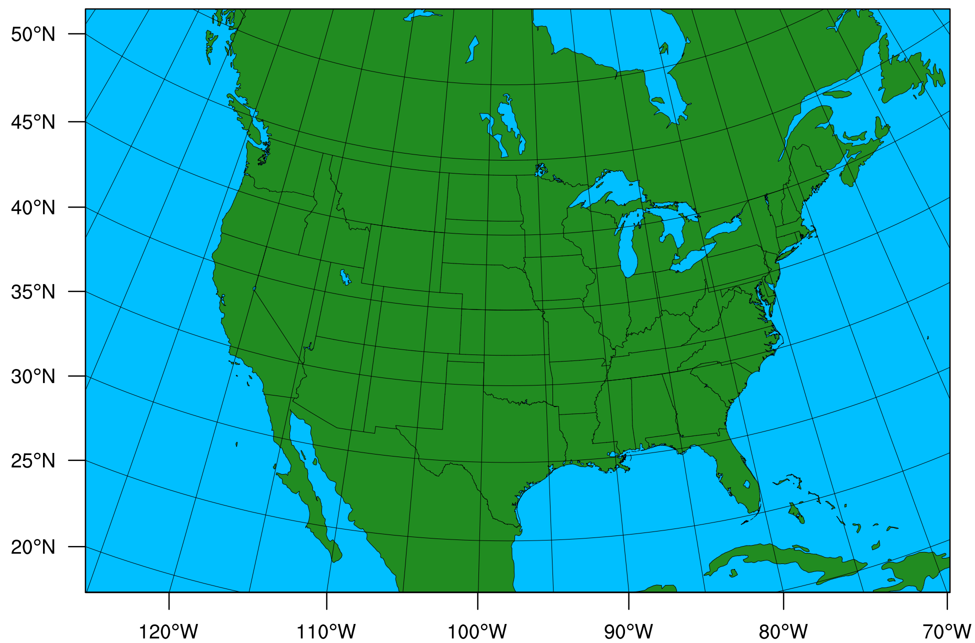

FIG. 2. domain configuration

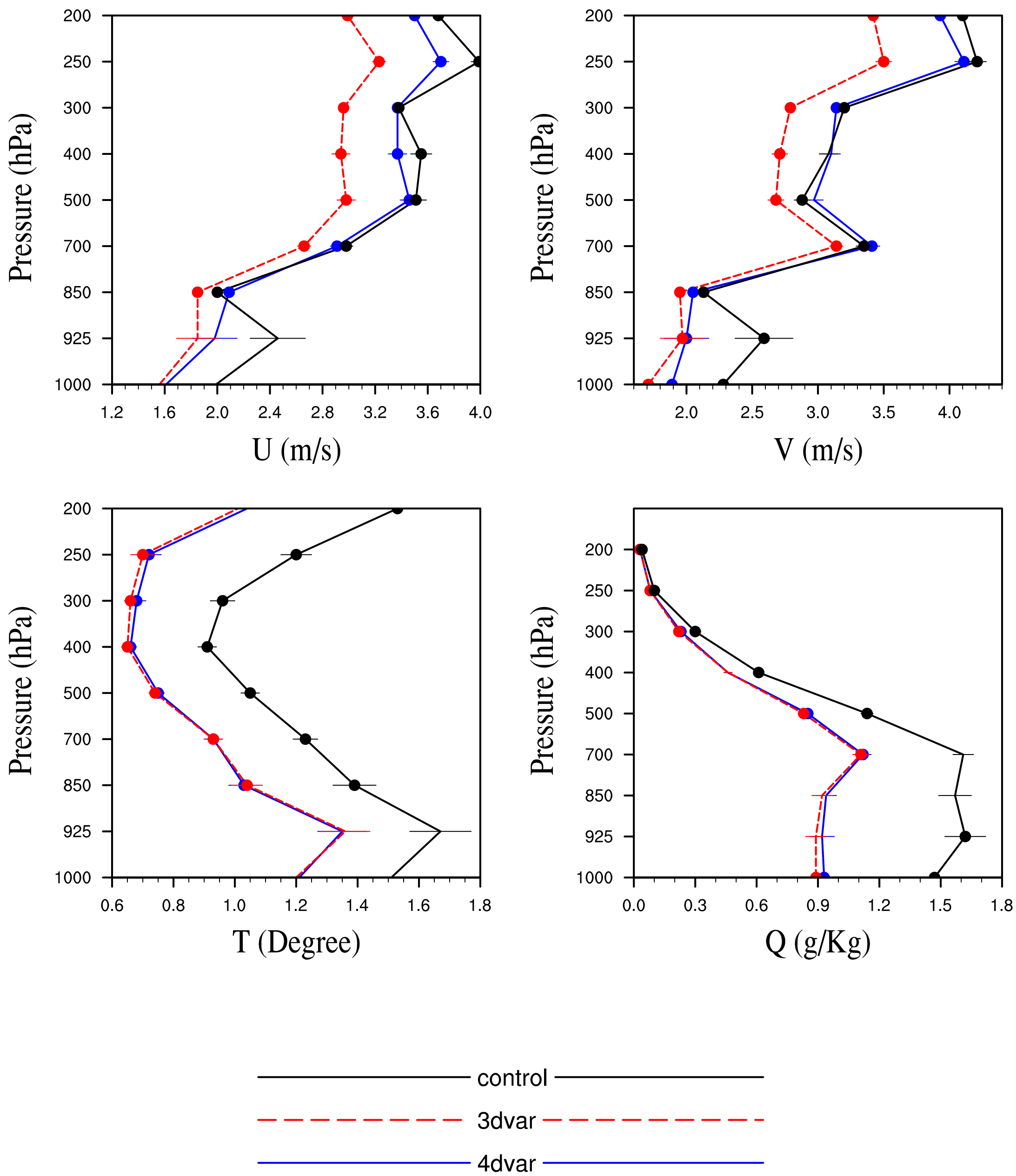

Fig. 3. Profile RMSE at 0h

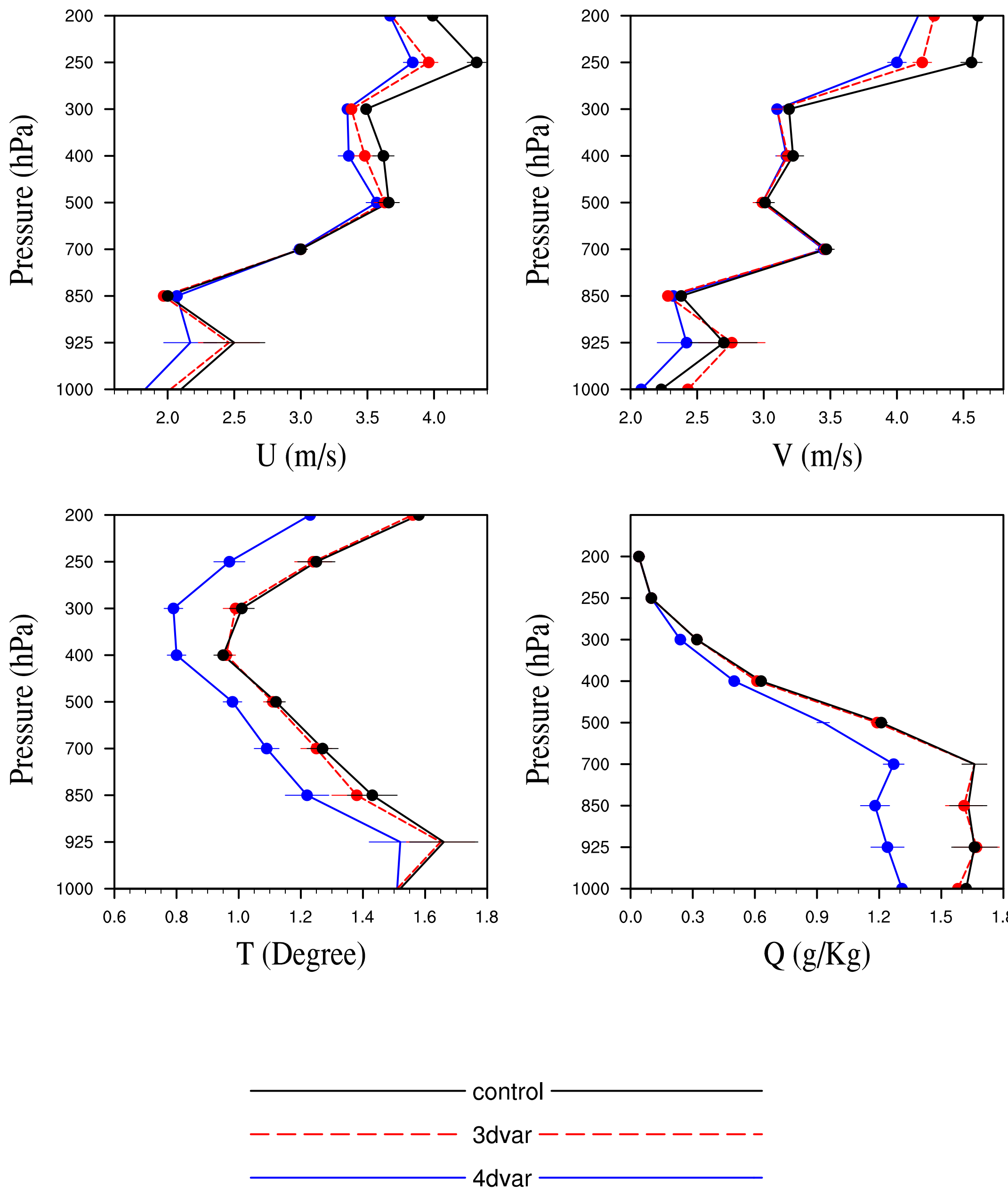

FIG. 4. Profile RMSE at 6h

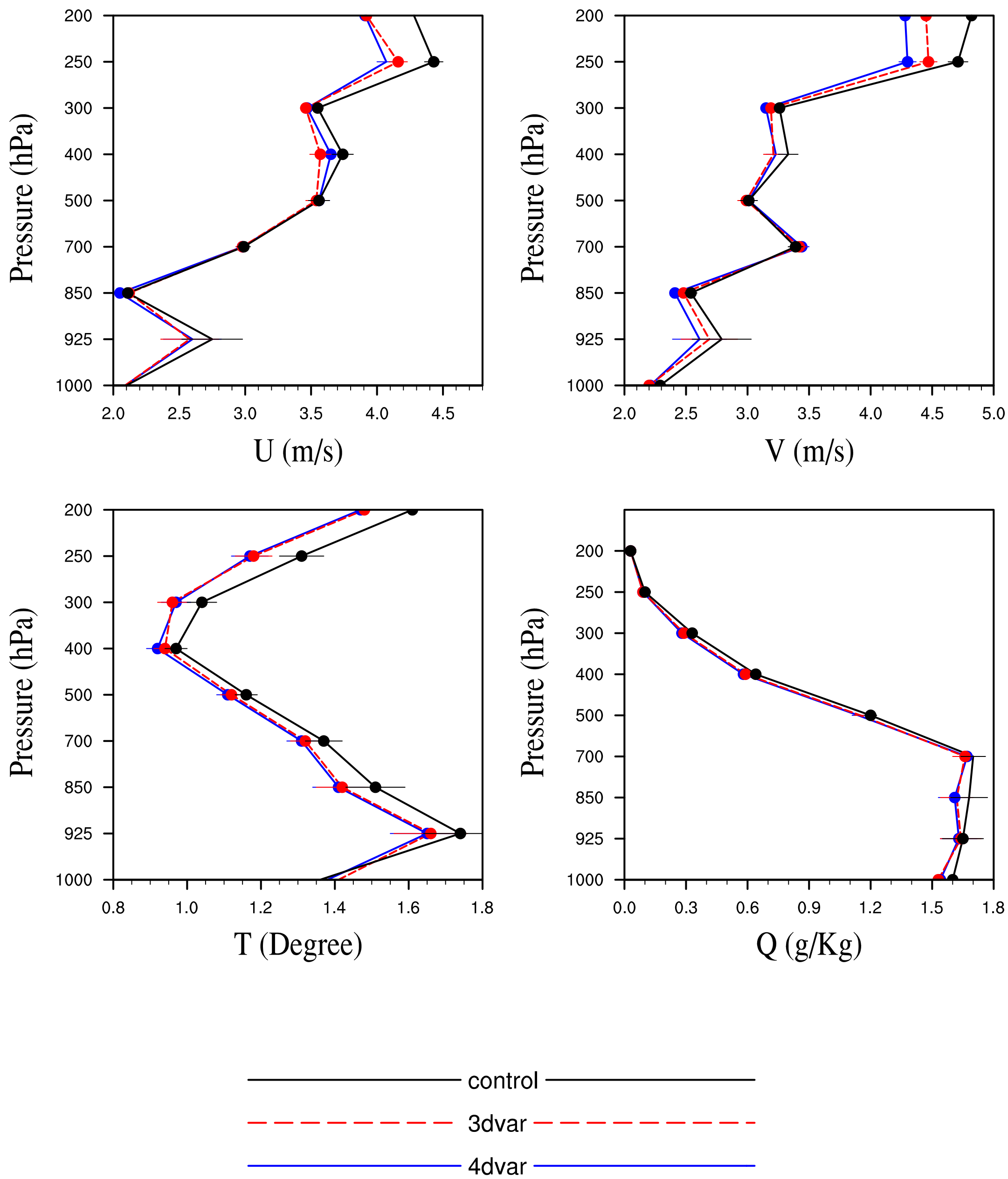

Fig. 5. Profile RMSE at 12h

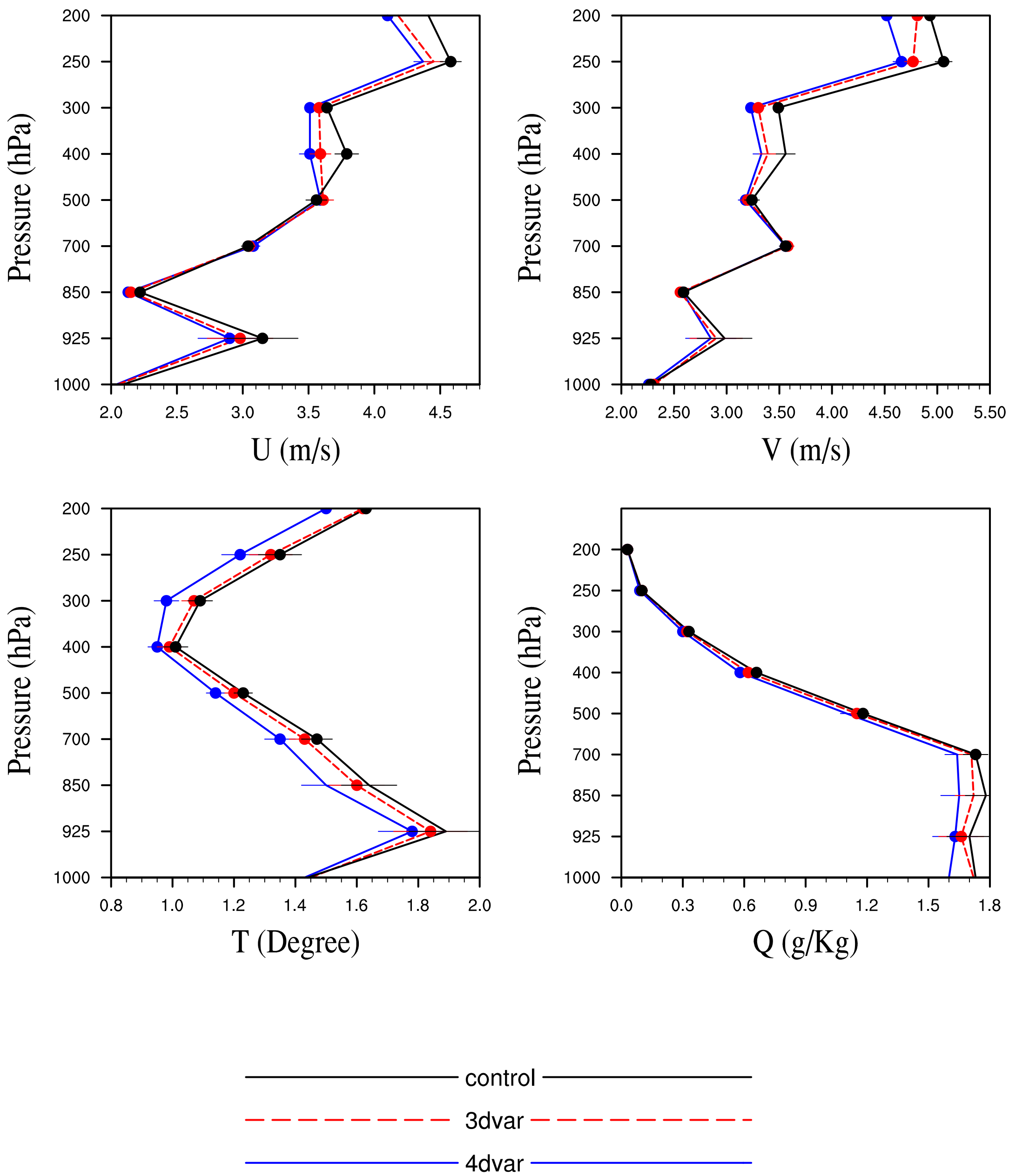

Fig. 6. Profile RMSE at 18h

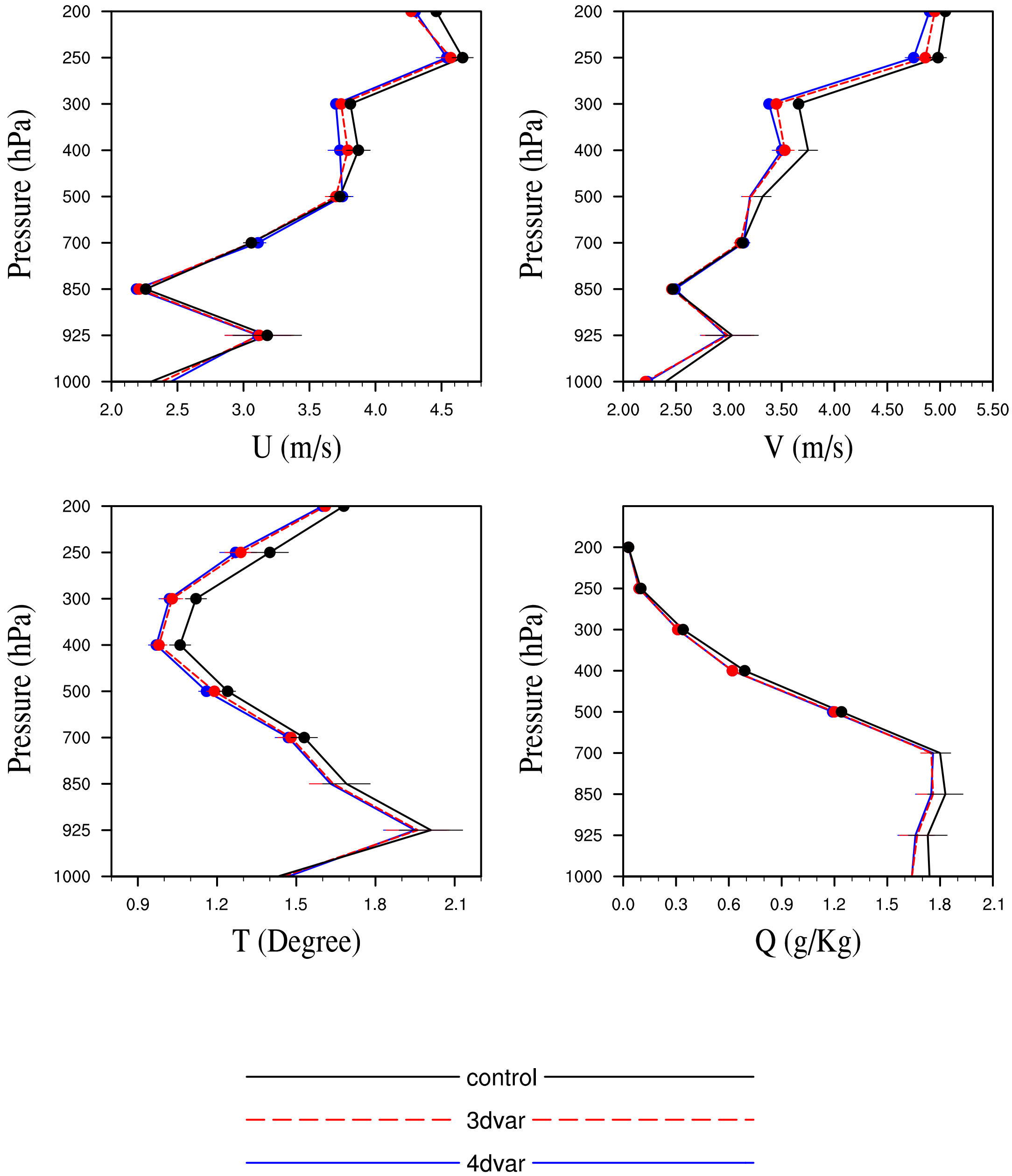

FIG. 7. Profile RMSE at 24h

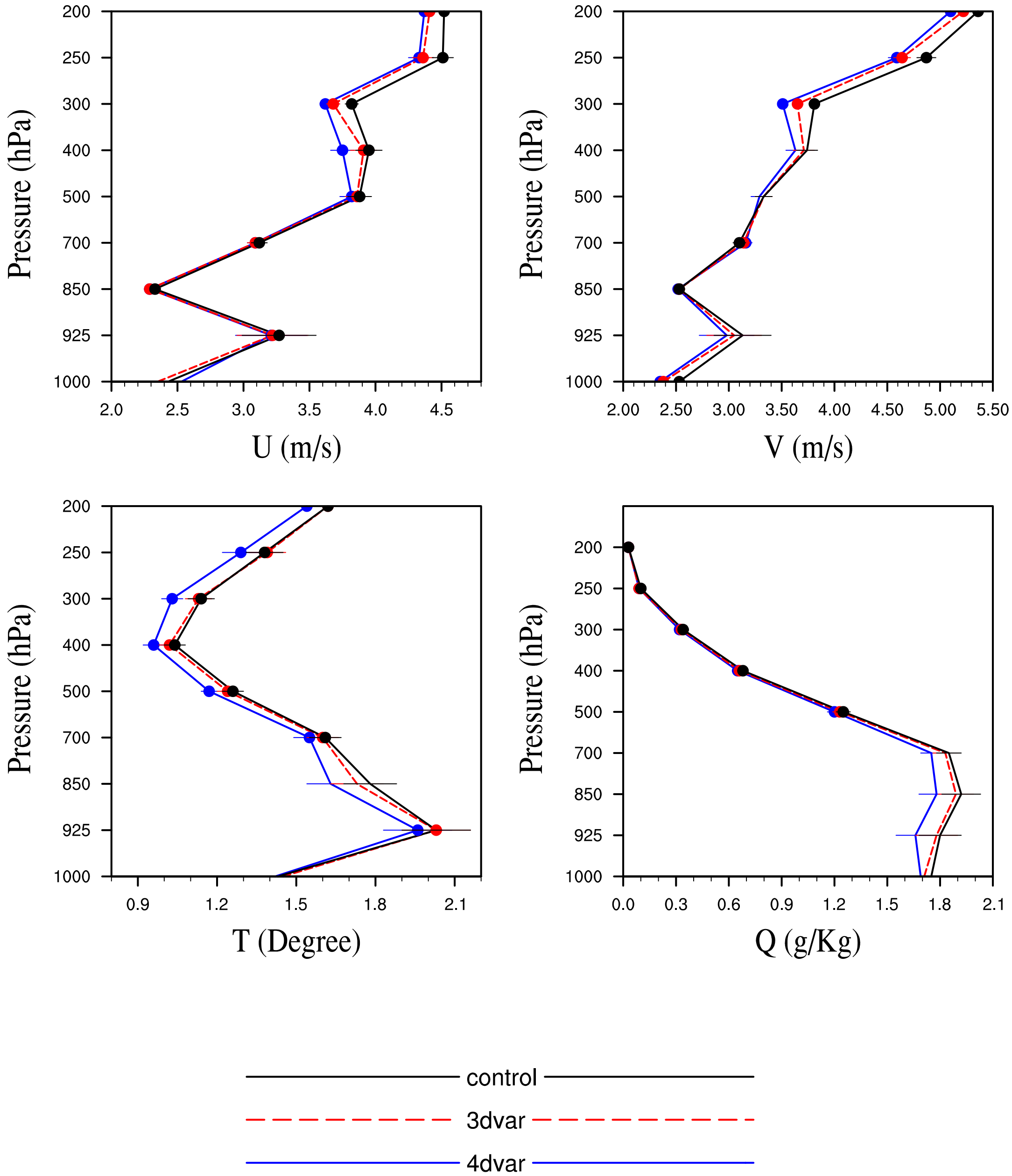

Fig. 8. Profile RMSE at 30h

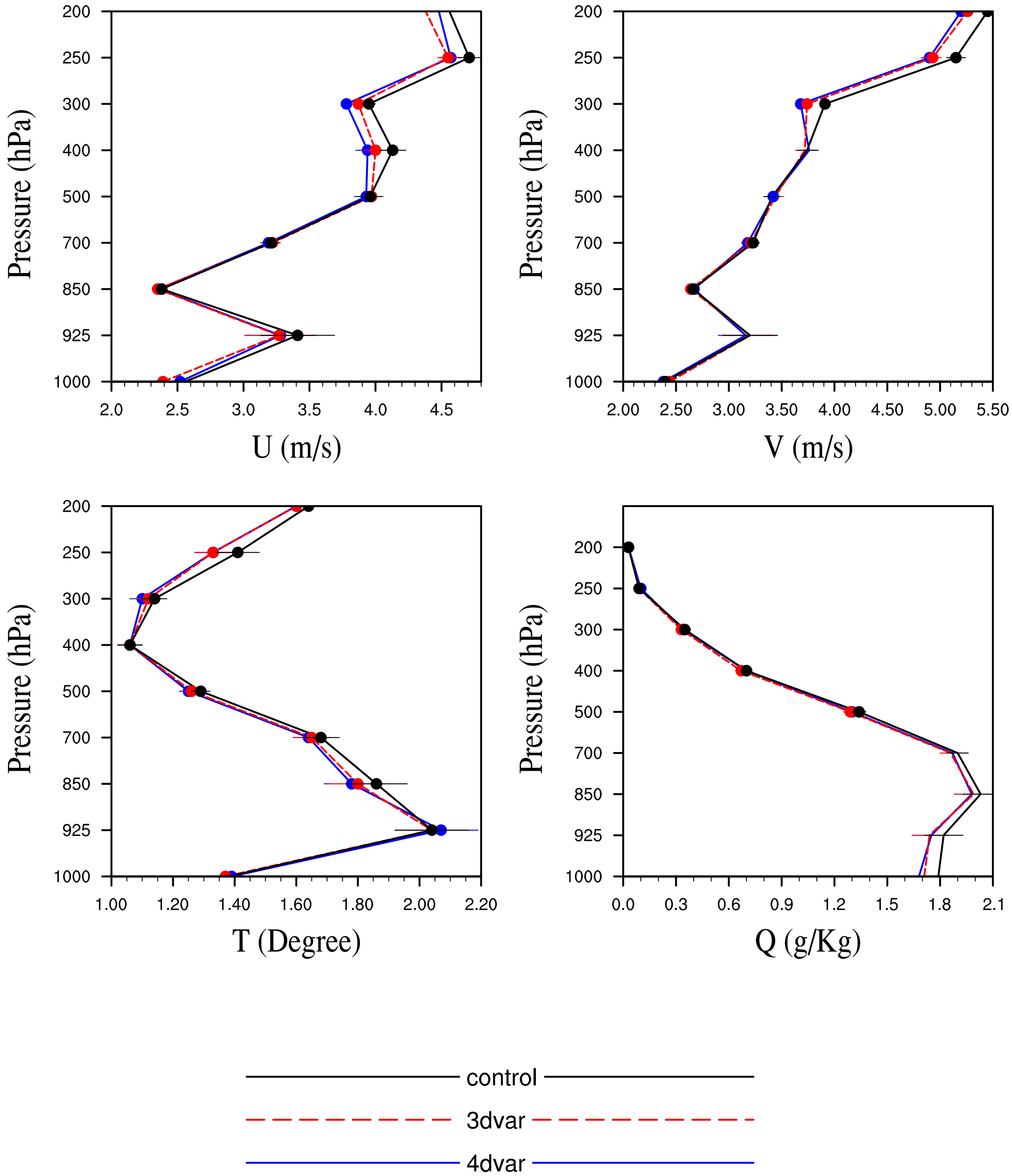

FIG. 9. Profile RMSE at 36h

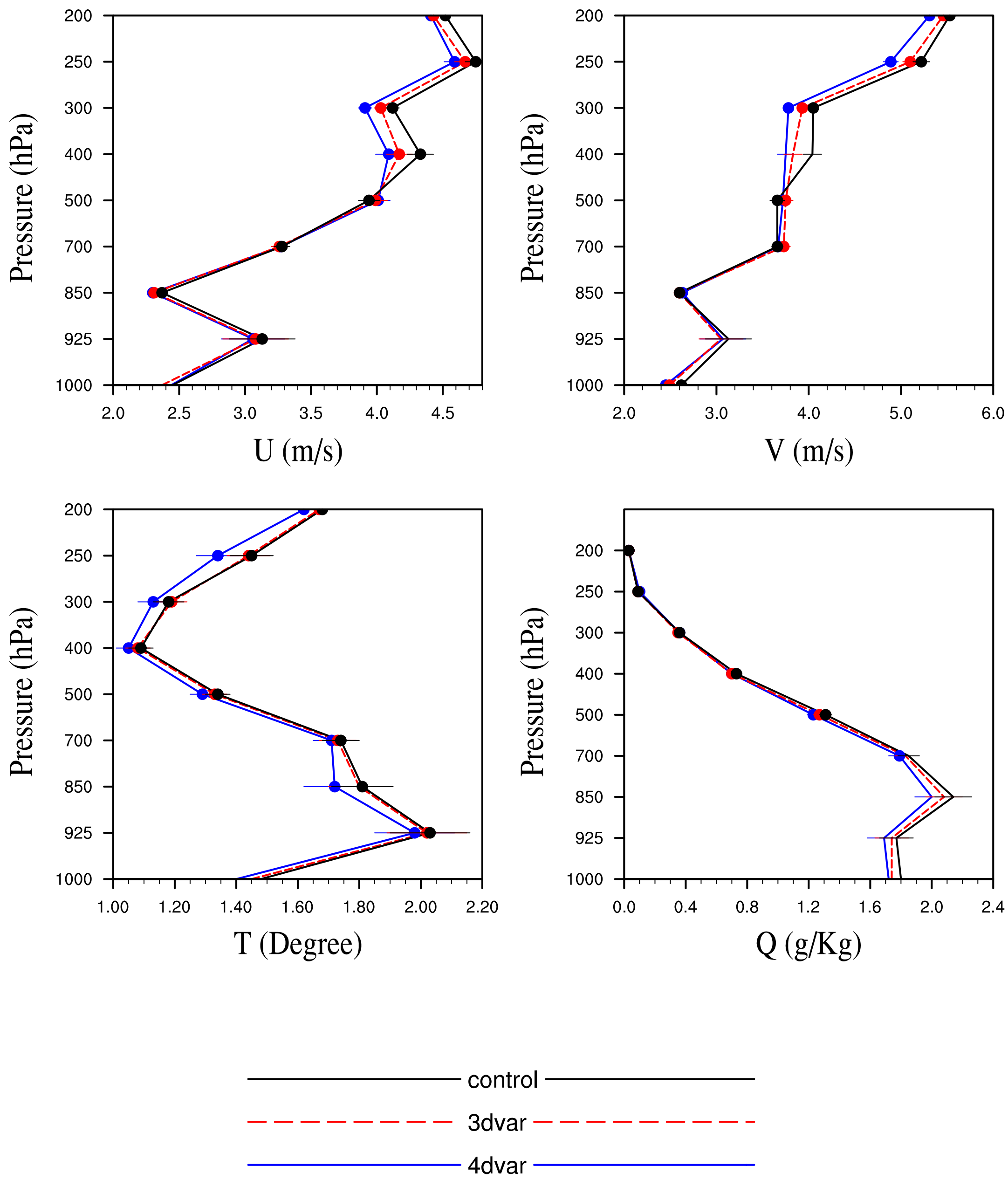

Fig. 10. Profile RMSE at 42h

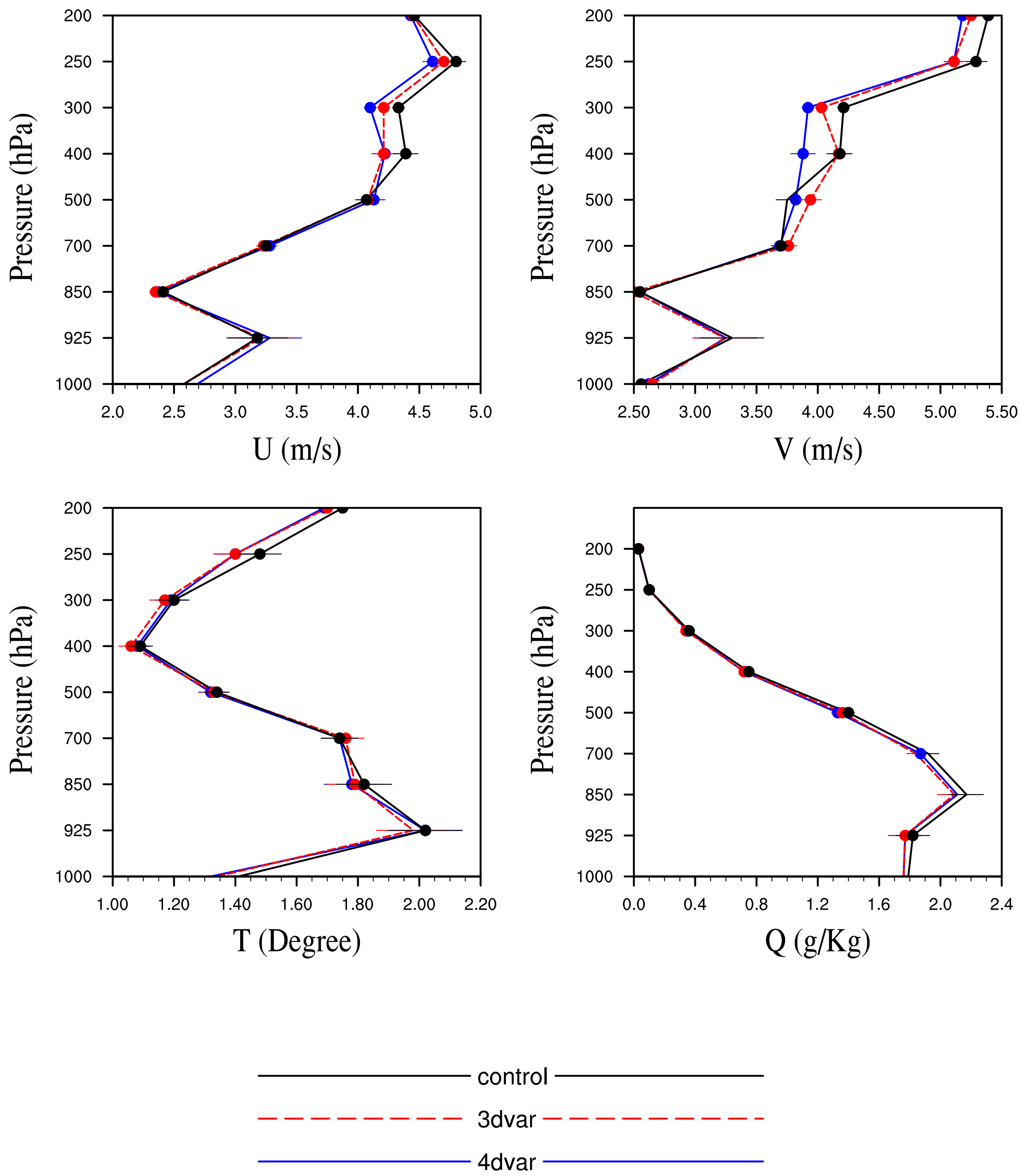

FIG. 11. Profile RMSE at 48h