

Report on the development of GSI-based WRF 4DVAR

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Outline

① Introduction



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② Upgrades of WRFPLUS



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- ④ GSI/WRF 4DVAR System Validation
 - Single observation exp.
 - Tutorial case
 - Real case



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Acknowledgement

Sincere thanks to Dr. Ricardo Todling, Dr. Thomas Auligne and Dr. Junmei Ban for their help and encouragement



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- The WRF tangent linear and adjoint codes (hereafter, WRFPLUS) have been updated to be consistent with the latest WRF repository codes
- Because the parallelization of the latest WRFPLUS is still on going, only 1 processor parallel run is doable at this moment



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- Add option to control if all inputs and outputs were happen in disk or memory, so WRFPLUS can be used as a standalone tool or as a component in 4DVAR system.



Sample 6h Tangent Linear and Adjoint Check

Tangent linear check

```
...
tl_check: alpha=.1000E-04  coef=0.10000447262220E+01
tl_check: alpha=.1000E-05  coef=0.99999981575068E+00
tl_check: alpha=.1000E-06  coef=0.99999998152933E+00
tl_check: alpha=.1000E-07  coef=0.99999990980017E+00
tl_check: alpha=.1000E-08  coef=0.99999956711797E+00
...
```

Adjoint check

```
ad_check: VAL_TL:      0.42476489986911E+11
ad_check: VAL_AD:      0.42476489986912E+11
```



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- Added WRF TL/AD subroutines calling interface in model_tl and model_ad
- Added capability to do adjoint test with WRF AD/TL.



Modification in GSI contd

GSI Boulder repository revision 585, 2011-02-15

```
M      src/main/wrf_binary_interface.F90
M      src/main/read_wrf_mass_files.f90
M      src/main/control2model.f90
M      src/main/update_guess.f90
M      src/main/model_t1.F90
M      src/main/control2state.f90
M      src/main/model_ad.F90
M      src/main/stub_pertmod.F90
M      src/main/pcgsoi.f90
M      src/main/adjtest.f90
M      src/main/read_prepbufr.f90
M      src/main/gsi_4dvar.f90
A      src/main/wrf_pertmod.F90
M      src/main/wrwrflmassa.F90
M      src/main/wrf_netcdf_interface.F90
M      src/main/gsimod.F90
M      src/main/model2control.f90
M      src/main/state2control.f90
M      src/main/read_wrf_mass_guess.F90
M      src/main/evaljgrad.f90
M      src/main/Makefile.dependency
M      src/main/obsmod.F90
```



NESL

The New Module wrf_pertmod

The coupler and utilities used to couple GSI and WRFPLUS.

```
module wrf_pertmod
    subroutine model_nl_wrf          ! Subroutine to call WRF nonlinear model
    ...
    end subroutine model_nl_wrf
    subroutine model_tl_wrf          ! Subroutine to call WRF tangent linear model
    ...
    end subroutine model_tl_wrf
    subroutine model_ad_wrf          ! Subroutine to call WRF adjoint model
    ...
    end subroutine model_ad_wrf
    subroutine gsi2wrf_tl            ! Transfer GSI perturbation to WRF perturbation
    ...
    end subroutine gsi2wrf_tl
    subroutine gsi2wrf_ad            ! Adjoint of gsi2wrf_tl
    ...
    end subroutine gsi2wrf_ad
    subroutine wrf2gsi_tl             ! Transfer WRF perturbation to GSI perturbation
    ...
    end subroutine wrf2gsi_tl
    subroutine wrf2gsi_ad            ! Adjoint of wrf2gsi_tl
    ...
    end subroutine wrf2gsi_ad
end module wrf_pertmod
```



Quick Start

Install WRFPLUS and GSI

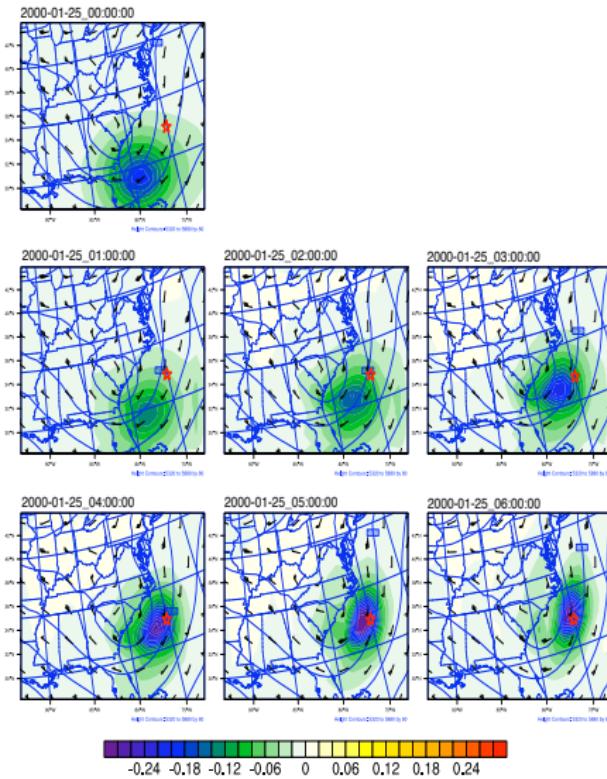
- WRFPLUS : WRF adjoint and tangent linear codes
 - > `configure [-d] wrfplus`
 - > `compile em_real`
- Set the the *WRF_DIR* environmental variable
 - > `setenv WRF_DIR full_path_of_wrfplus`
- GSI
 - > `configure`
 - > `compile`



Single observation exp.

- Initial time: 2000_01_25_00 : 00 : 00
- Ending time: 2000_01_25_06 : 00 : 00
- Observation: 500 mb Temperature at **ending time**
 $O - B = -1.17K$
- To investigate the difference at **ending time** between the forecast from analysis and from background.





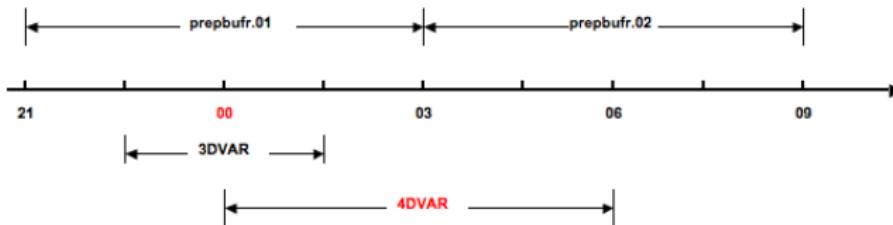
Remarks

Forecasted 500mb T difference
(DA forecast - reference
forecast)

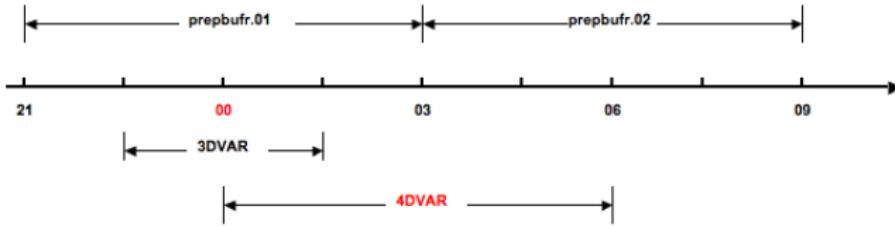
- \star is the location of obs. at the ending time (6h).
- Initial perturbation is on the upstream of the obs.
- Evolved perturbation at 6h hit the obs. location
- Very obvious flow dependent characteristics



Tutorial case – Observation Usage



Tutorial case – Observation Usage



3DVAR

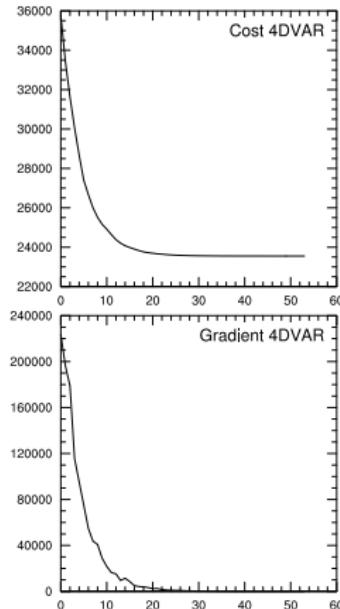
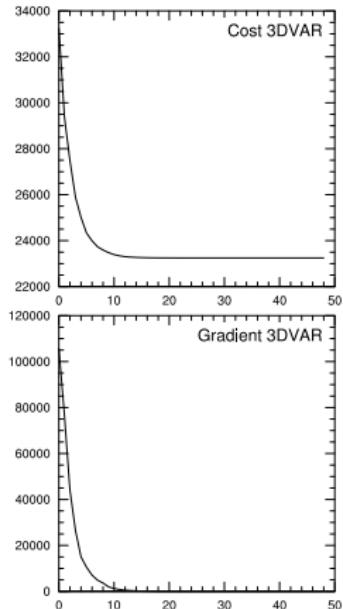
0:OBS_PARA: ps	13842
0:OBS_PARA: t	20114
0:OBS_PARA: q	18743
0:OBS_PARA: uv	30894
0:OBS_PARA: spd	48
0:OBS_PARA: sst	503
0:OBS_PARA: pw	880
-----Total-----	
47675	

4DVAR

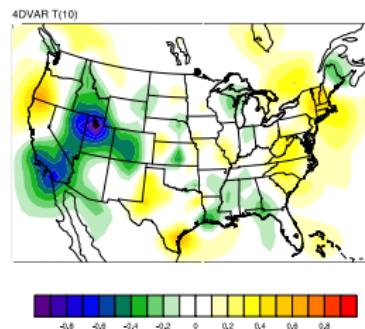
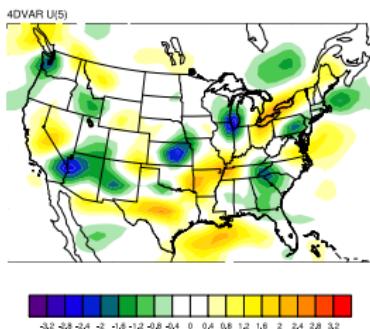
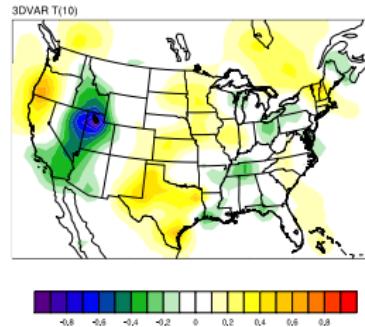
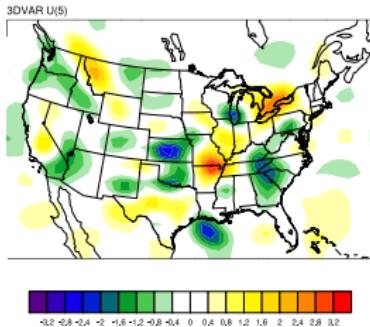
0:OBS_PARA: ps	13585
0:OBS_PARA: t	20639
0:OBS_PARA: q	19180
0:OBS_PARA: uv	28802
0:OBS_PARA: spd	80
0:OBS_PARA: sst	494
0:OBS_PARA: pw	766

0:OBS_PARA: ps	10
0:OBS_PARA: t	552
0:OBS_PARA: q	490
0:OBS_PARA: uv	568
-----Total-----	
45040 ???	

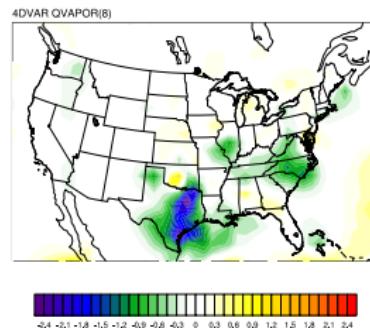
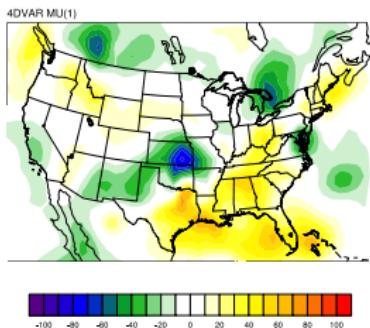
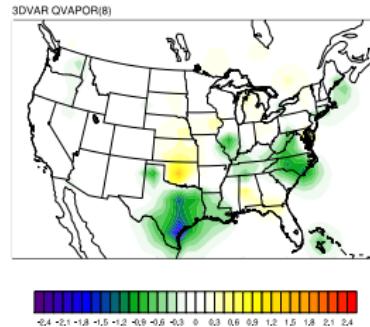
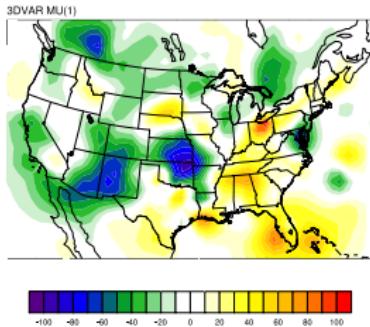
Cost functions and gradients



Sample increments comparison – U, T

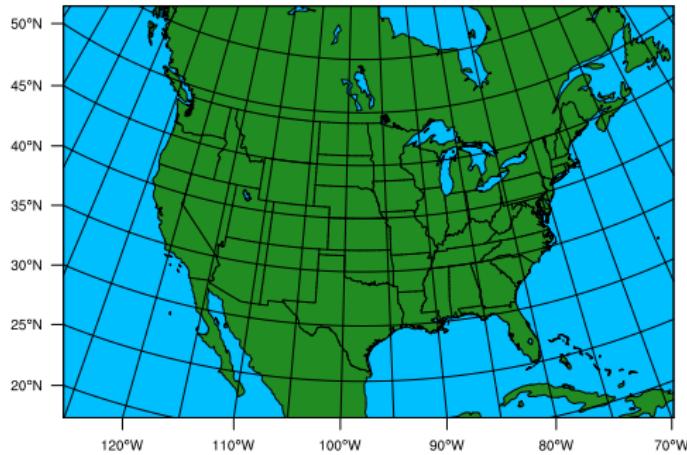


Sample increments comparison – MU, QVAPOR

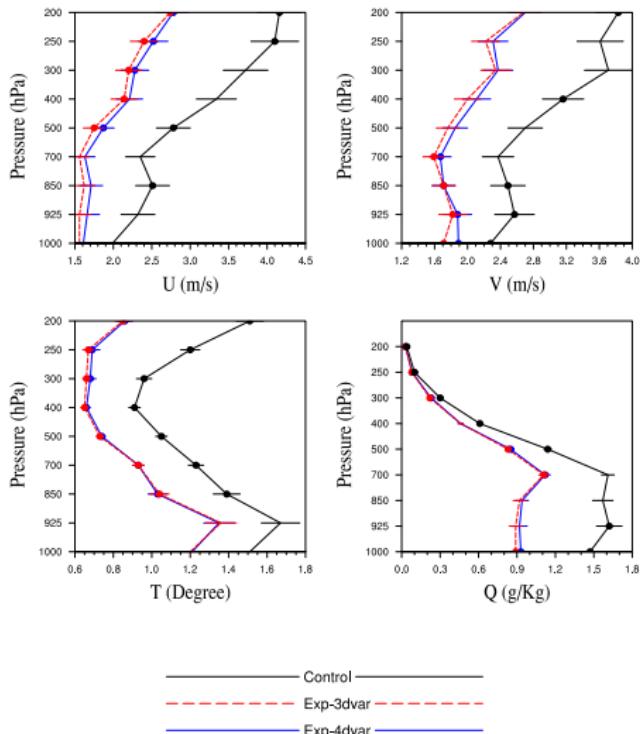


Domain

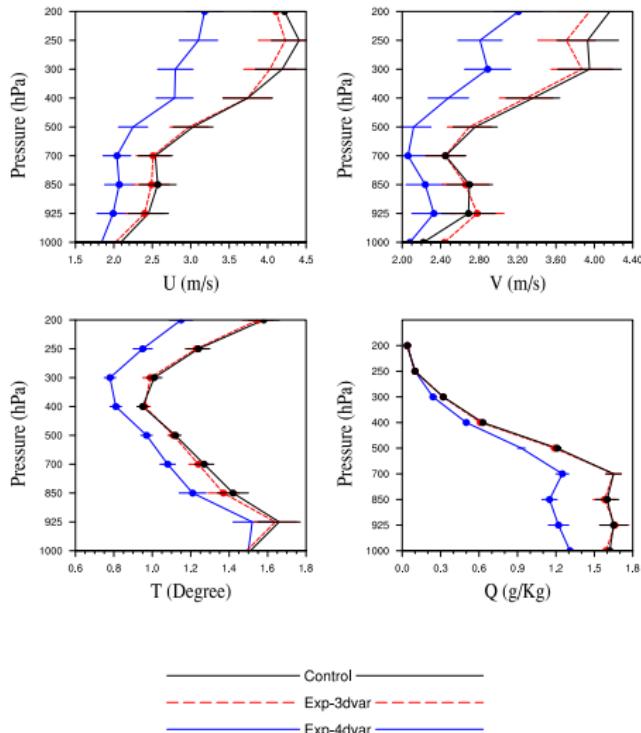
- Grids: 47x32x28L
- Resolution: 135km
- Period: 2007091000-2007091300 @0Z,6Z,12Z,18Z
- First guess is the 12h forecast from NCEP FNL
- 48h forecast from FG, 3DVAR and 4DVAR



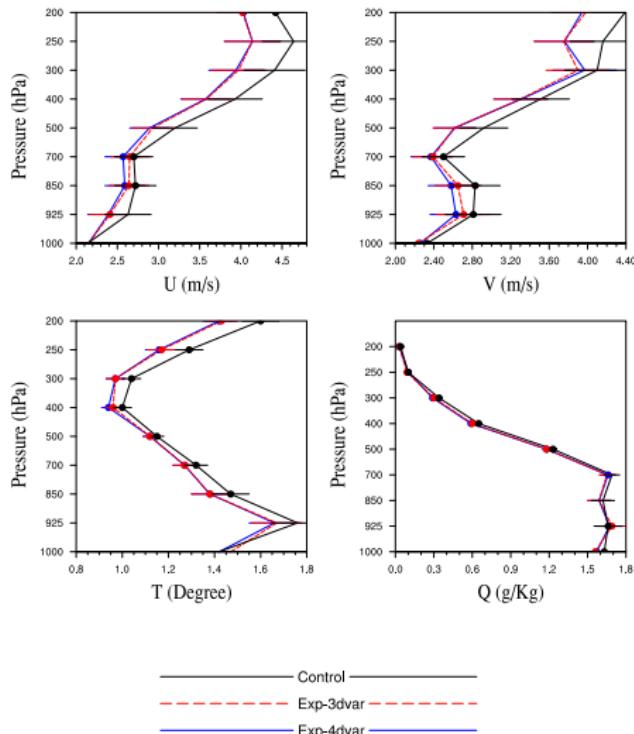
RMSE Verification—00h



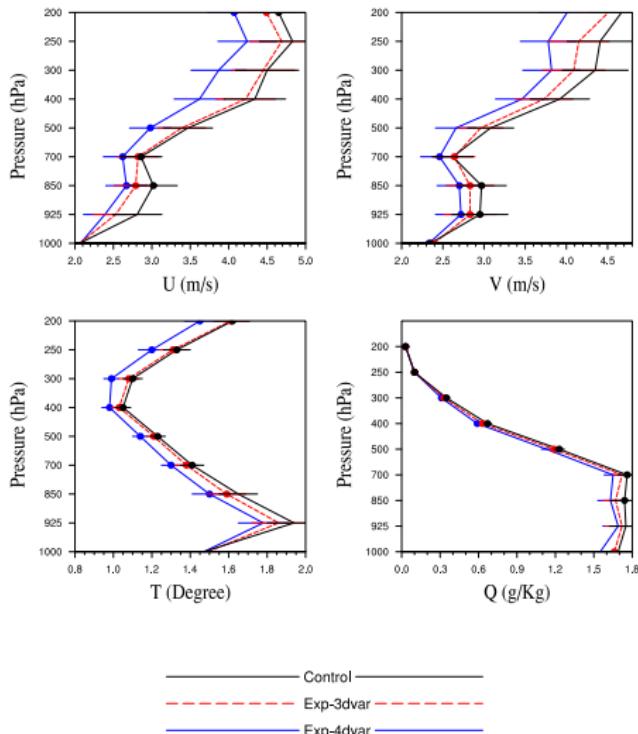
RMSE Verification—06h



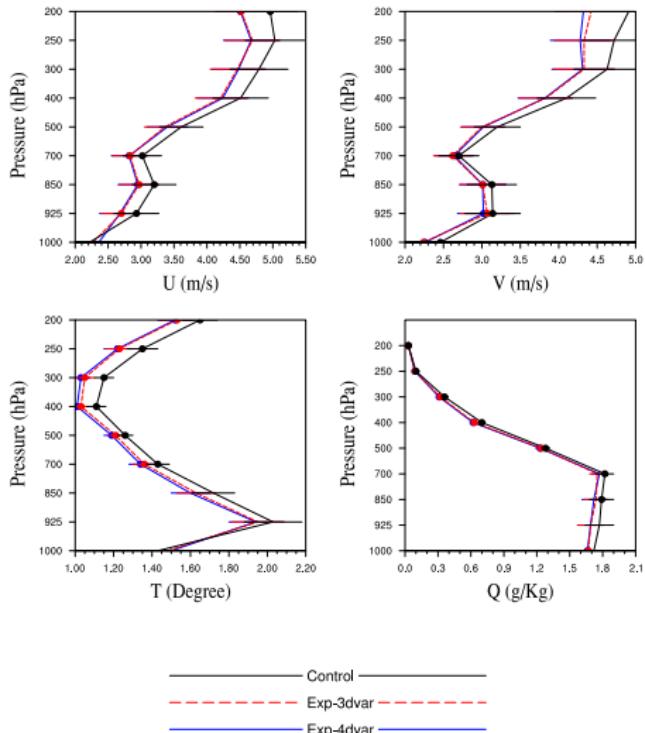
RMSE Verification—12h



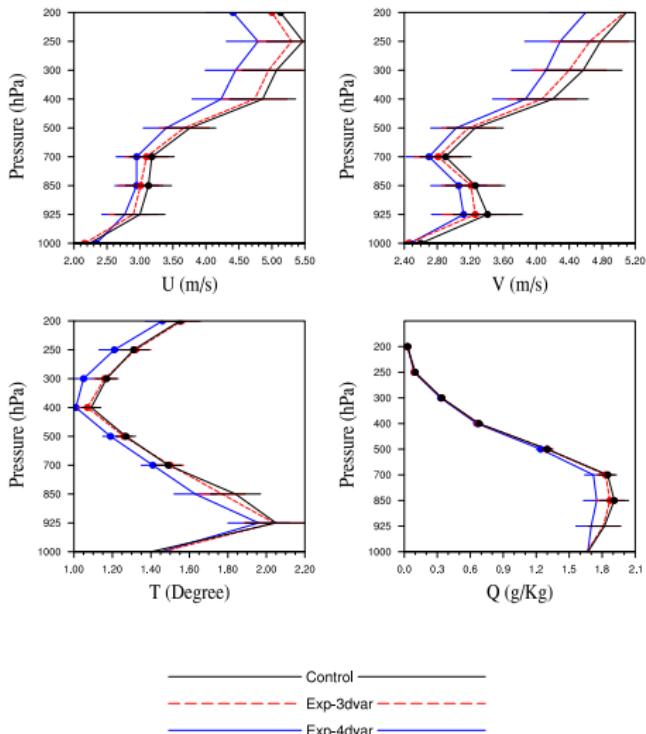
RMSE Verification—18h



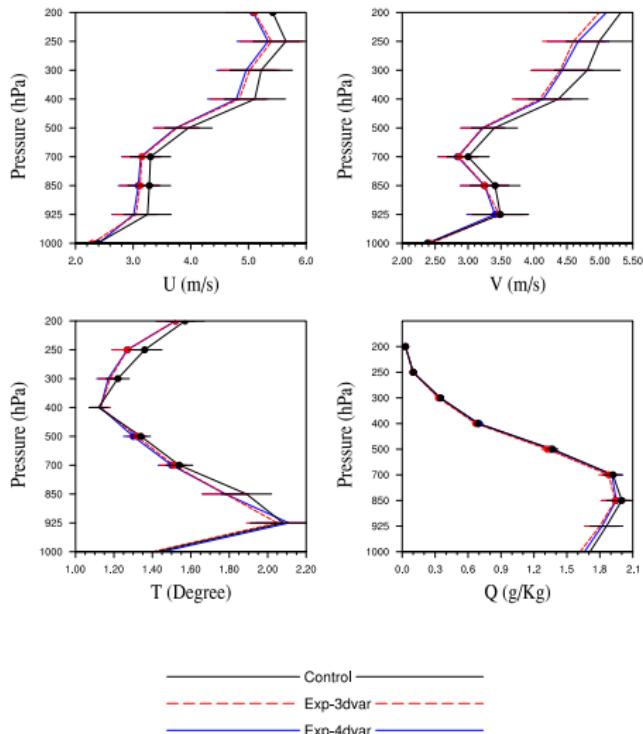
RMSE Verification—24h



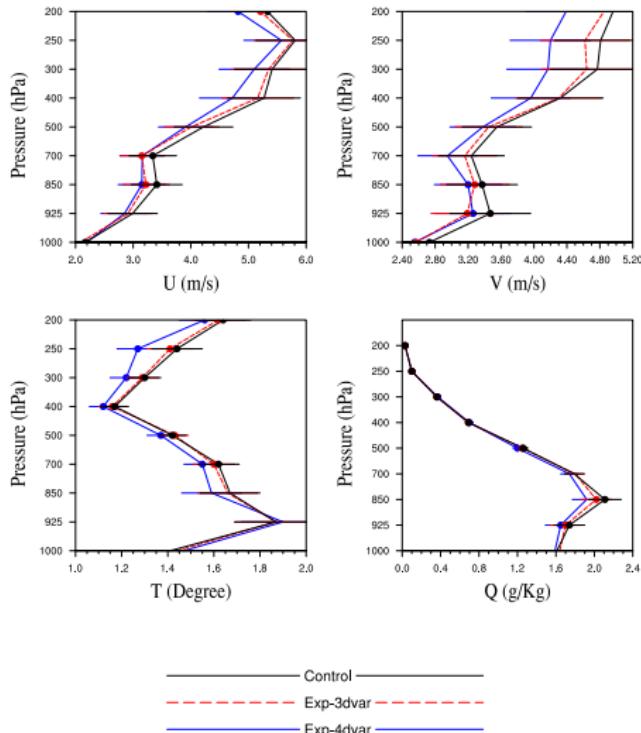
RMSE Verification—30h



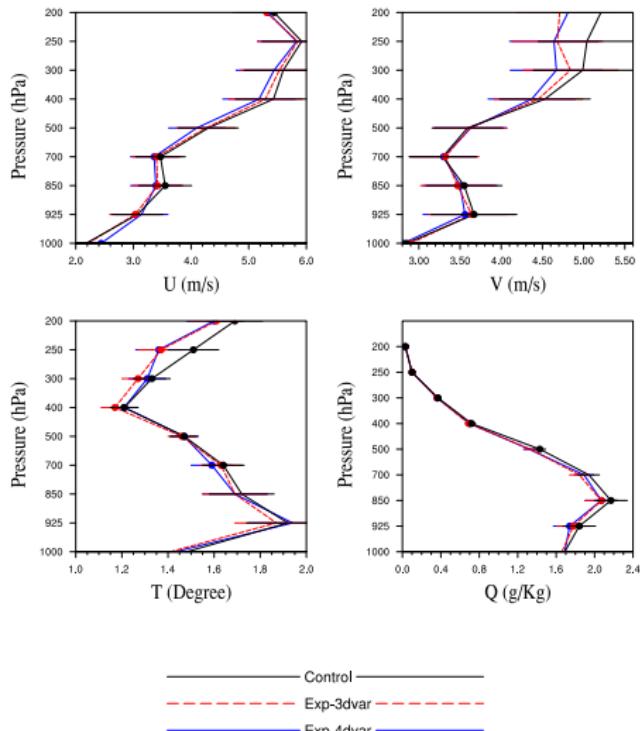
RMSE Verification—36h



RMSE Verification—42h



RMSE Verification—48h



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- The single observation exp. preliminarily confirm that the system is valid and is able to produce flow dependent increments.
- The increments produced by 4DVAR run with tutorial case are comparable with the 3DVAR run.



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- Adapt digital filter as a weak constrain for GSI-based WRF 4DVAR.



Thank You

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To provide facility support to the wider community; and,
To apply the results to benefit society.

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