

# 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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- ③ New developments in GSI



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  - Single observation exp.
  - Tutorial case
  - Real case



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# Acknowledgement

*Sincere thanks to Dr. Ricardo Todling for his help to kick off the project.*

*Sincere thanks to Dr. Thomas Auligne, Dr. Junmei Ban, Mrs. Xiaoyan Zhang and Mr. Feng Gao 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 a new module which serves the hub between GSI and WRFPLUS
- 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/wrvrflmassa.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
```



# 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

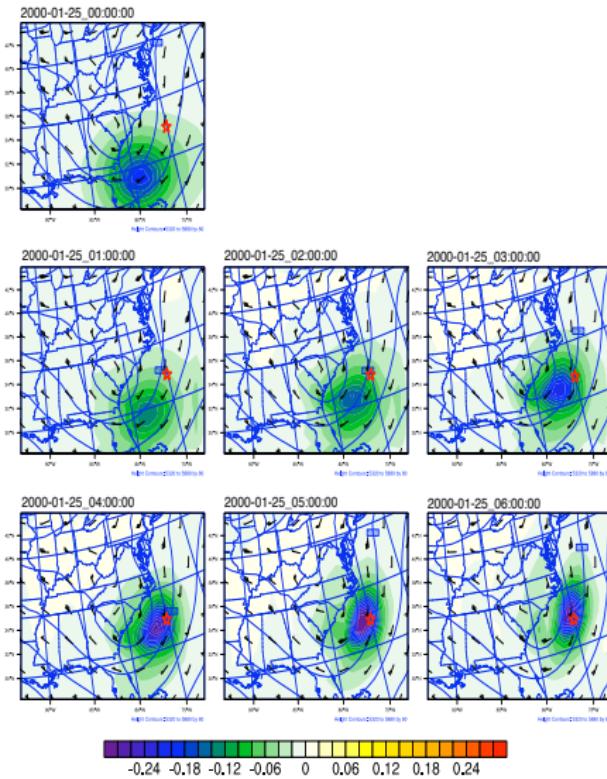
- WRFPLUS : WRF adjoint and tangent linear codes
  - > `configure [-d] wrfplus`
  - > `compile em_real`
- Set the the *WRF\_DIR* environmental variable
  - > `setenv WRF_DIR full_path_of_wrfplus`
- GSI
  - > `configure`
  - > `compile`



# 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.





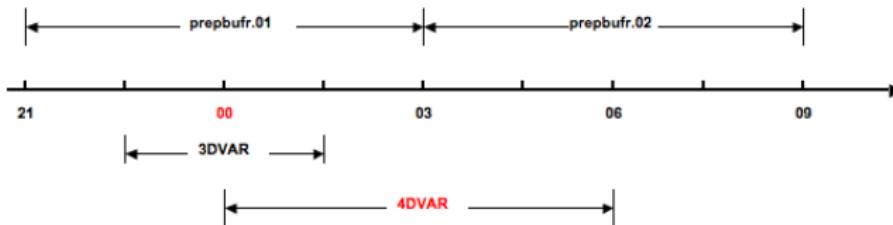
## Remarks

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

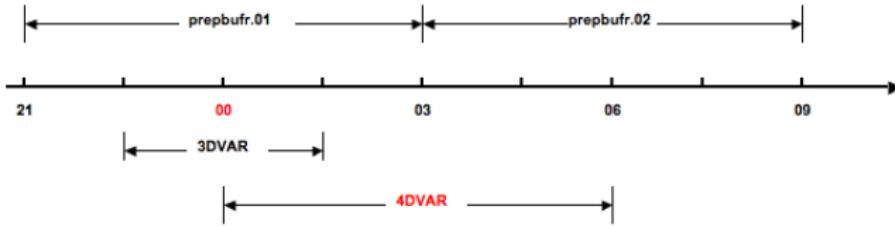
- $\star$  is the location of obs. at the ending time (6h).
- Initial perturbation is on the upstream of the obs.
- Evolved perturbation at 6h hit the obs. location
- Very obvious flow dependent characteristics



# Tutorial case – Observation Usage



# Tutorial case – Observation Usage



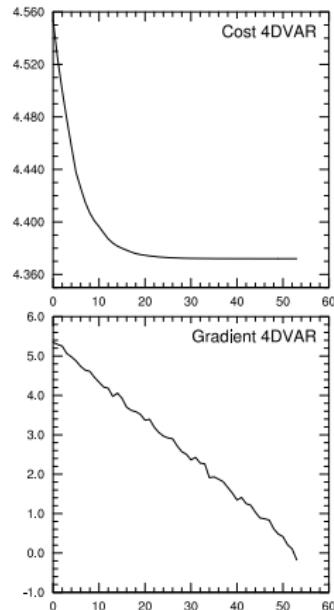
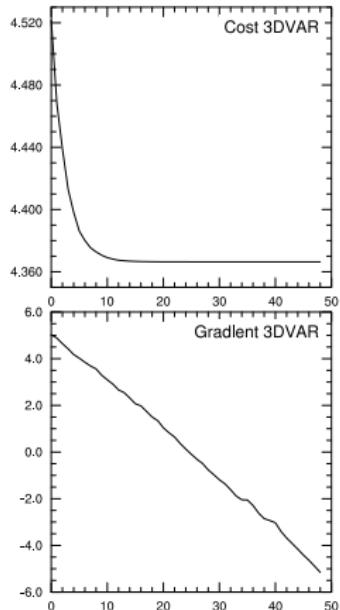
## 3DVAR

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

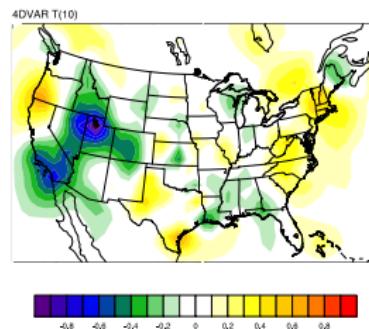
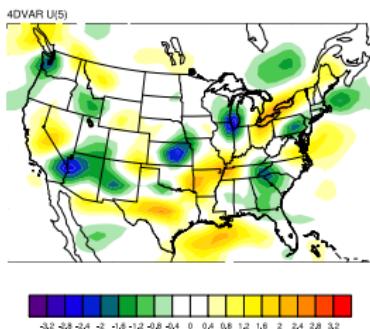
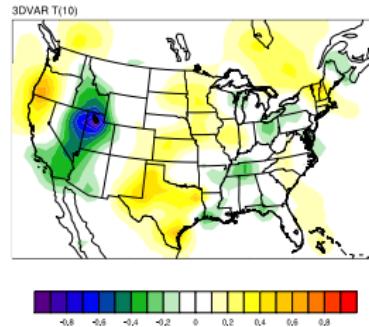
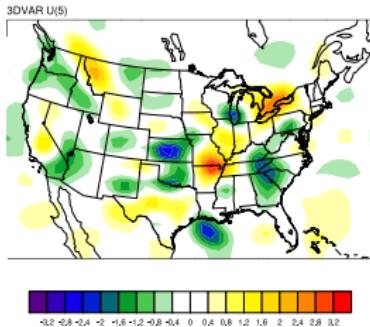
## 4DVAR

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 ???

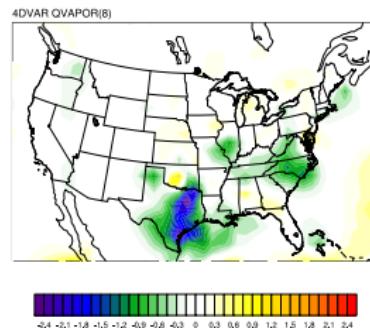
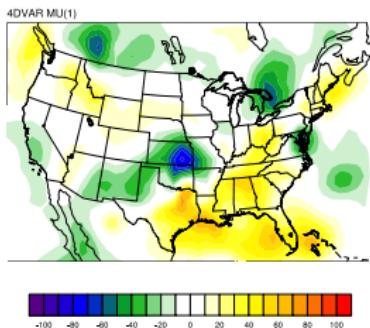
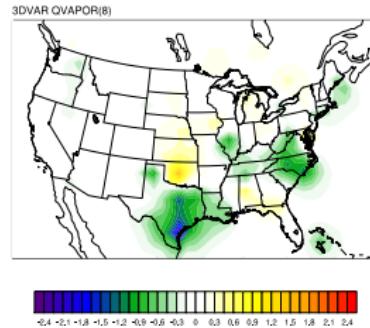
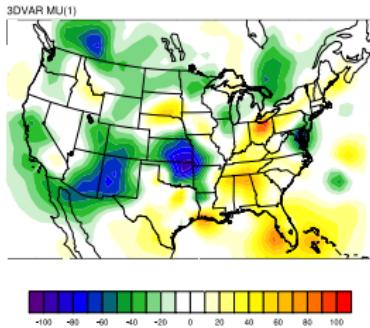
# Cost functions and gradients –scaled by ALOG10



# Sample increments comparison – U, T

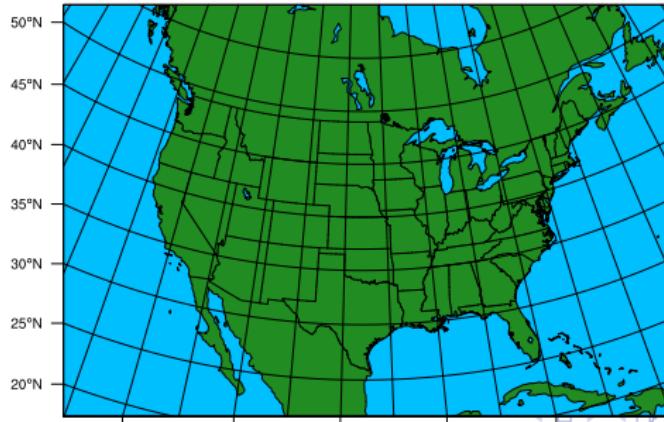


# Sample increments comparison – MU, QVAPOR

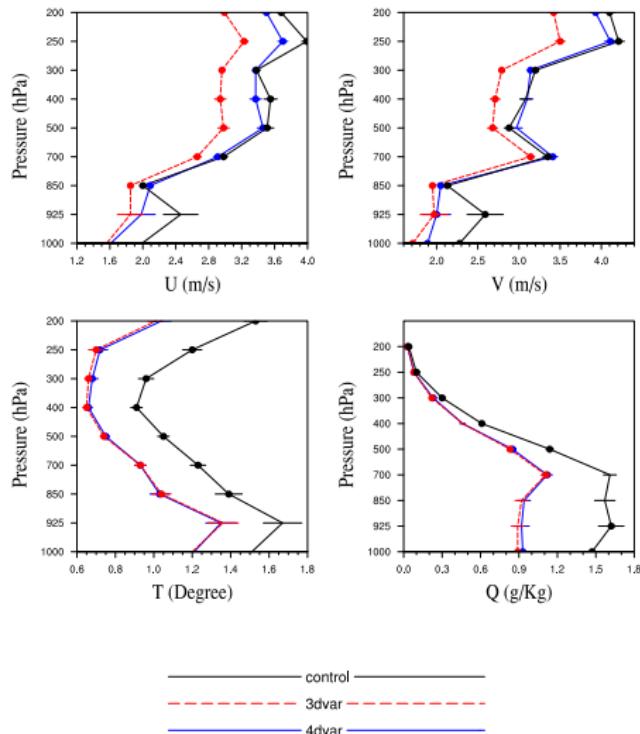


# Domain

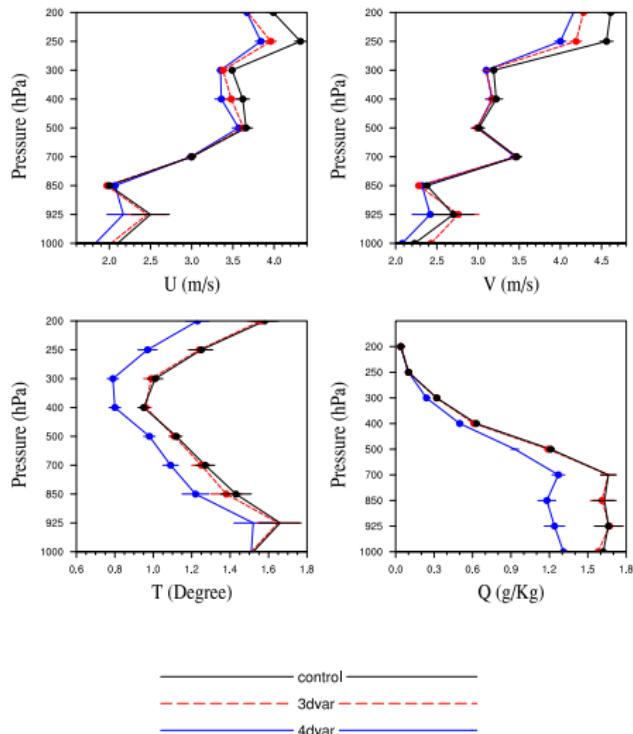
- Grids: 47x32x28L
- Resolution: 135km
- Period: 2007091000-2007091300 @0Z,6Z,12Z,18Z
- First guess is the 12h forecast from NCEP FNL
- 48h forecast from FG, 3DVAR and 4DVAR
- Verified against NCAR archived little\_r format data, filtered by FNL.



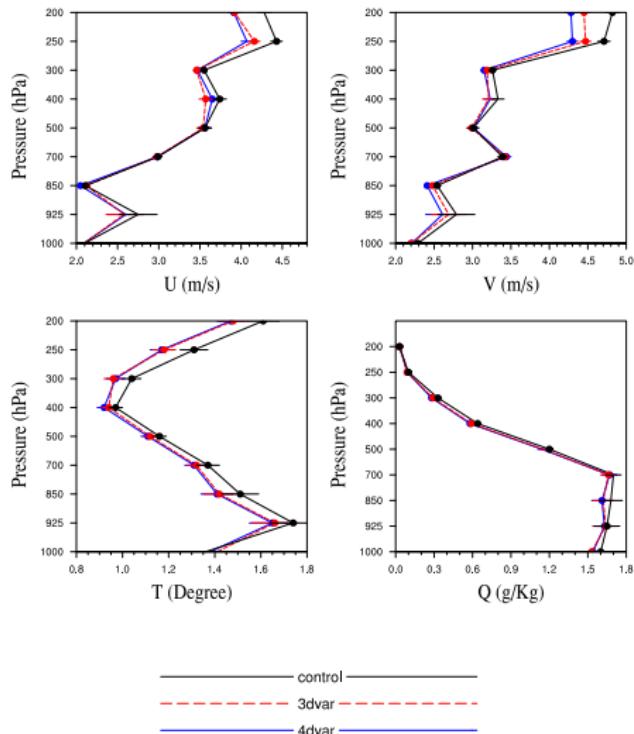
# RMSE Verification—00h



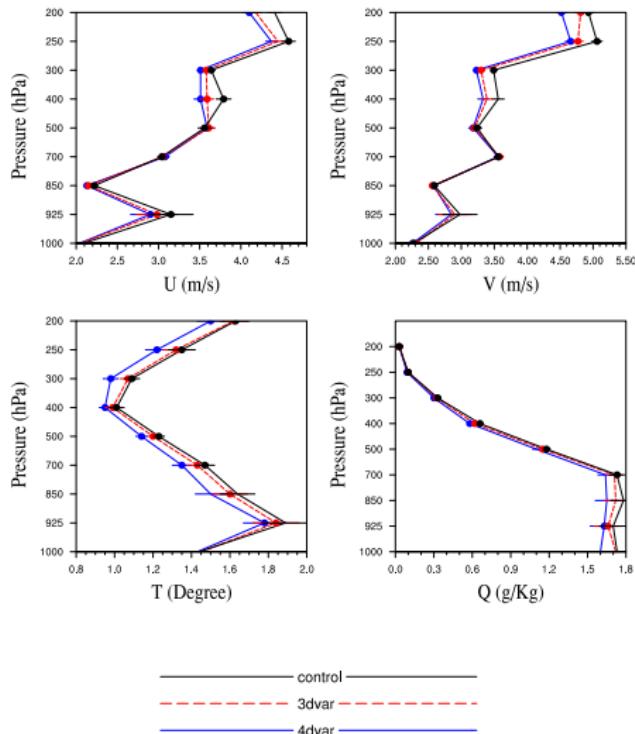
# RMSE Verification—06h



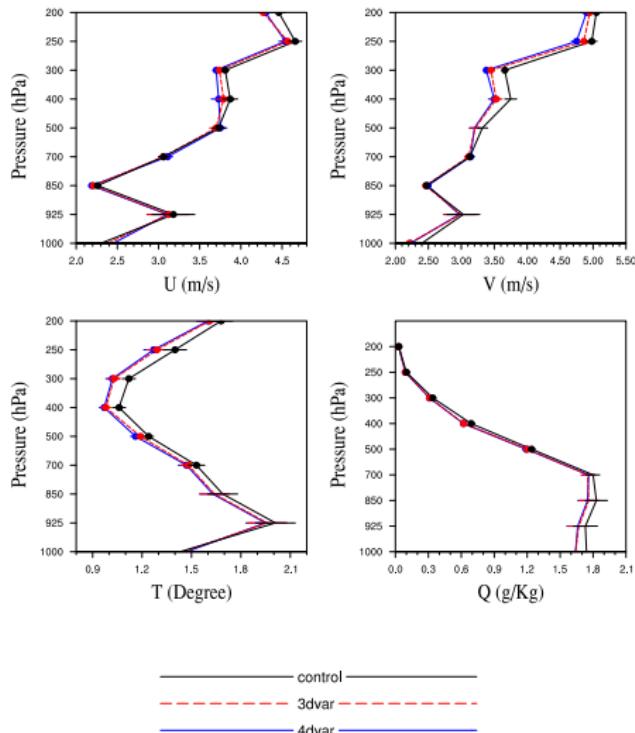
# RMSE Verification—12h



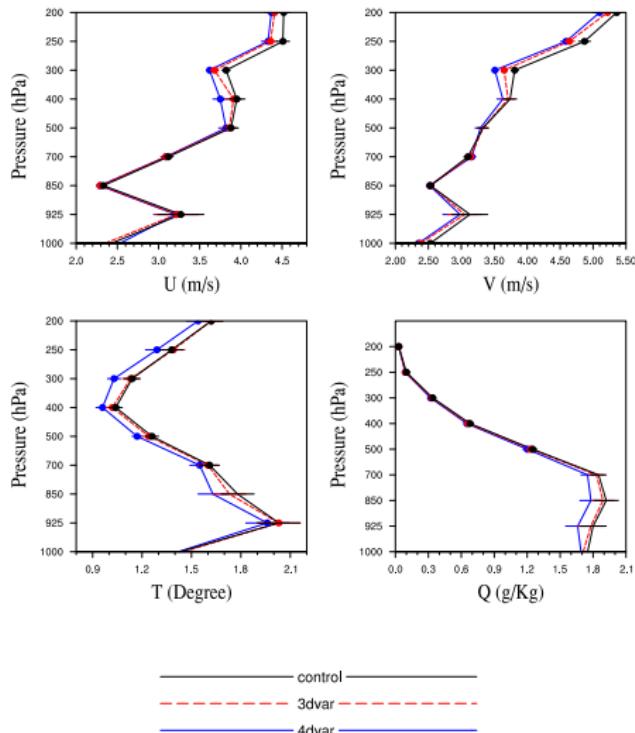
# RMSE Verification—18h



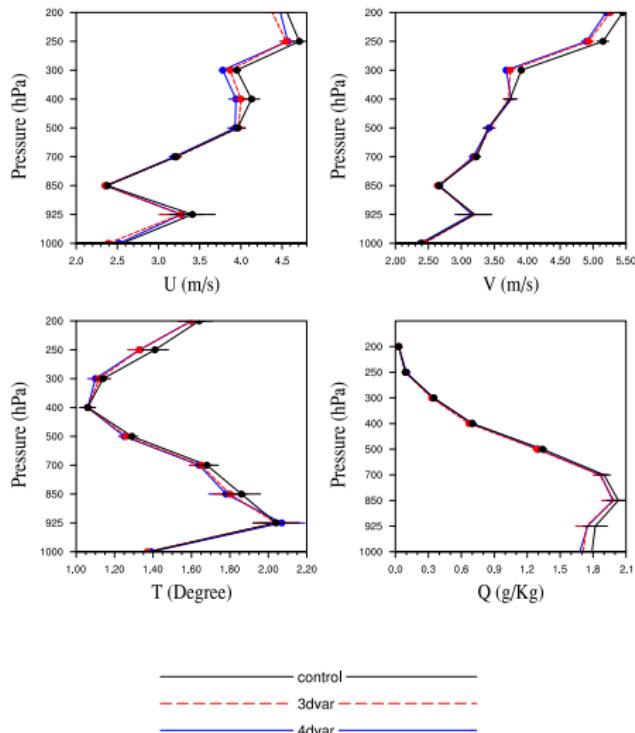
# RMSE Verification—24h



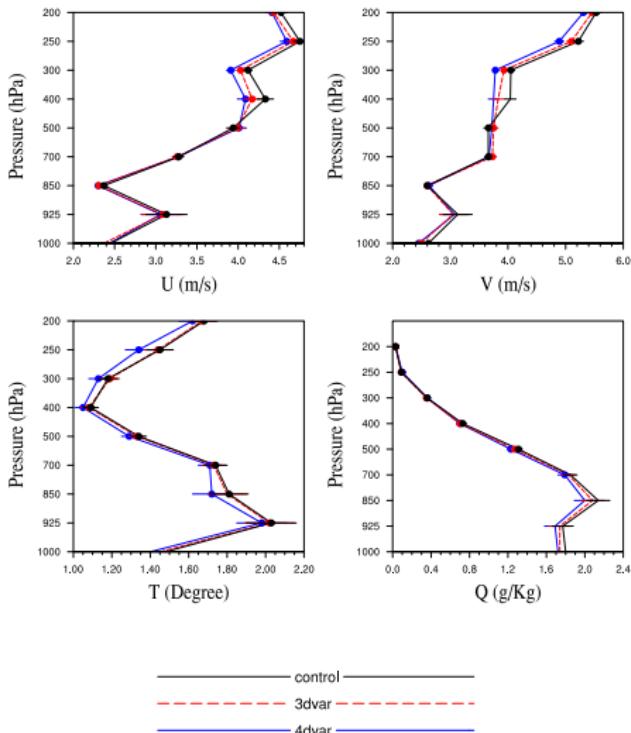
# RMSE Verification—30h



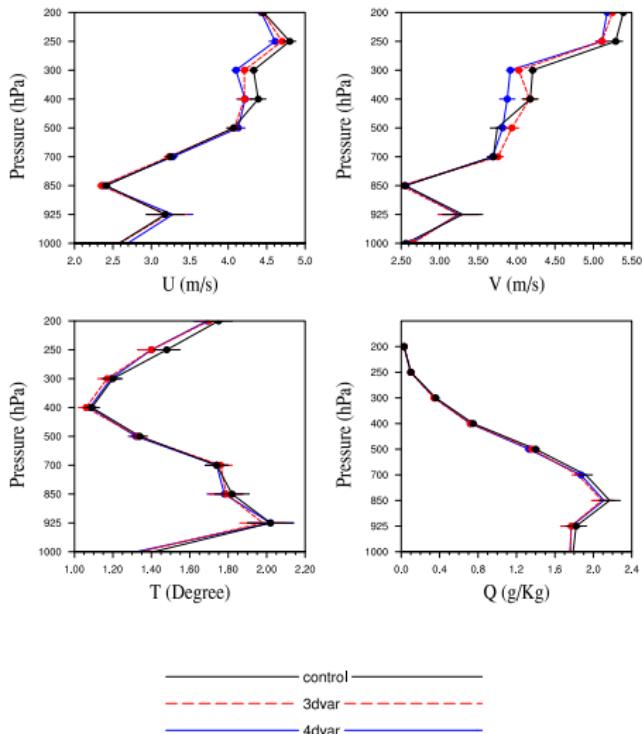
# RMSE Verification—36h



# RMSE Verification—42h



# RMSE Verification—48h



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- The real case shows the desirable performance of 4DVAR.



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- Assimilation of radiance data.
- Adapt gradient check for GSI-based WRF 4DVAR.
- 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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