

Report on the development of GSI-based WRF 4DVAR

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February 17, 2011

NCAR is sponsored by the National Science Foundation



Outline

① Introduction



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② Upgrades of WRFPLUS



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③ New developments in GSI



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- ① Introduction
- ② Upgrades of WRFPLUS
- ③ New developments in GSI
- ④ GSI/WRF 4DVAR System Validation
 - Single observation exp.
 - Tutorial case
 - Real case
 - Quick Start



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- ⑤ Summary



Acknowledgement

Sincere thanks to Dr. Ricardo Todling who helped us to kick off the project.



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- The Major development in GSI had finished, GSI codes had been coupled with the WRF tangent linear and adjoint model
- 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 capability to do tangent linear check and adjoint test over any length of time window.



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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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Modification in GSI

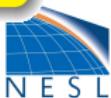
- Modified the capabilities to read and process multiple first guess and process obs. data for multiple time slots (?)
- Added a new module which serves the hub between GSI and WRFPLUS
- Added WRF TL/AD subroutines calling interface in model_tl and model_ad
- Added capability to do adjoint test with 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/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
```



The New Module wrf_pertmod

The coupler and utilities used to couple GSI and WRFPLUS.

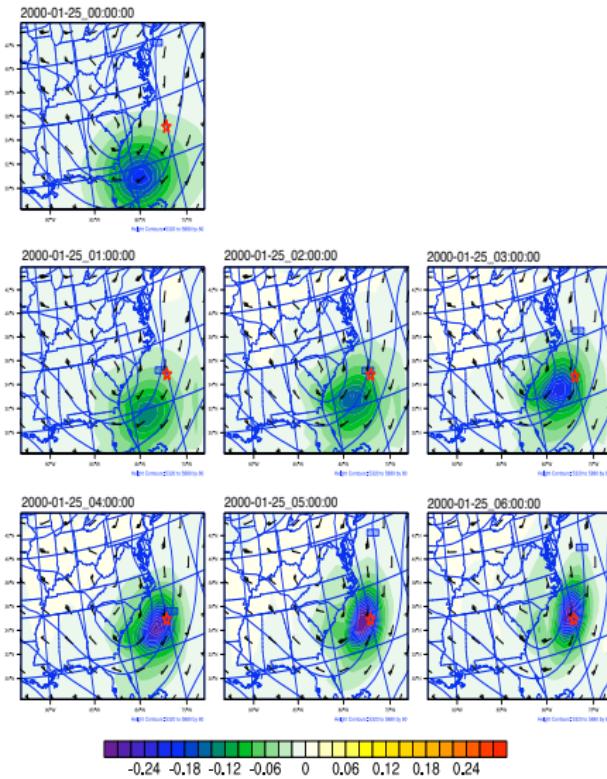
```
module wrf_pertmod
    subroutine model_nl_wrf          ! Subroutine to call WRF nonlinear model
    ...
    end subroutine model_nl_wrf
    subroutine model_tl_wrf          ! Subroutine to call WRF tangent linear model
    ...
    end subroutine model_tl_wrf
    subroutine model_ad_wrf          ! 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
```



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.





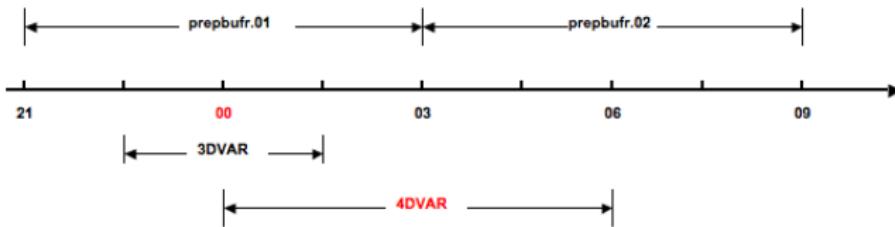
Remarks

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

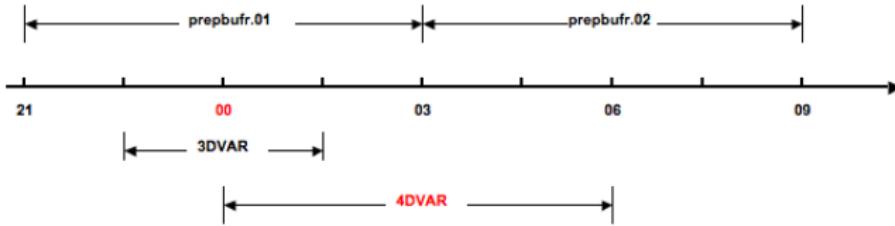
- ★ is the location of obs. at the ending time (6h).
- Initial perturbation is on the upstream of the obs.
- Evolved perturbation at 6h hit the obs. location
- Very obvious flow dependent characteristics



Tutorial case – Observation Usage



Tutorial case – Observation Usage



3DVAR

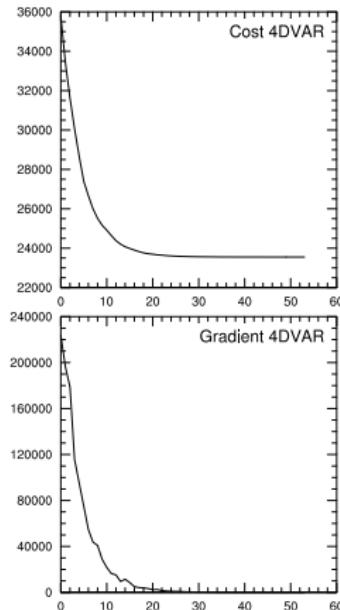
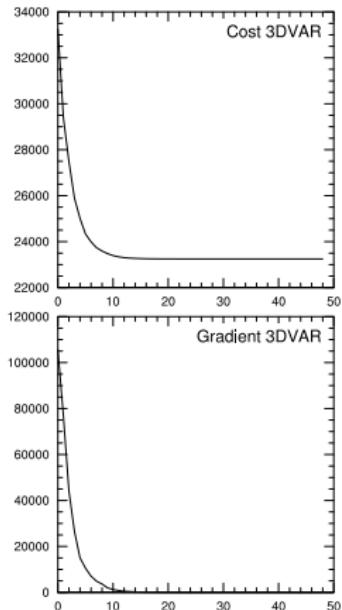
0:OBS_PARA: ps	13842
0:OBS_PARA: t	20114
0:OBS_PARA: q	18743
0:OBS_PARA: uv	30894
0:OBS_PARA: spd	48
0:OBS_PARA: sst	503
0:OBS_PARA: pw	880
-----Total-----	
47675	

4DVAR

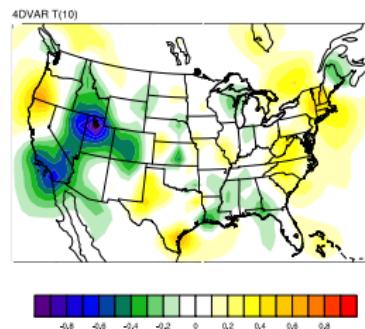
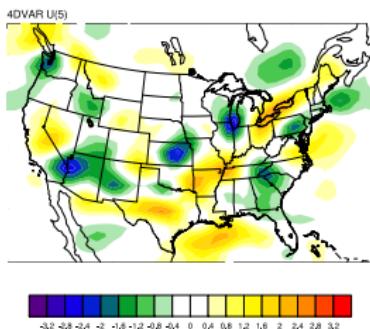
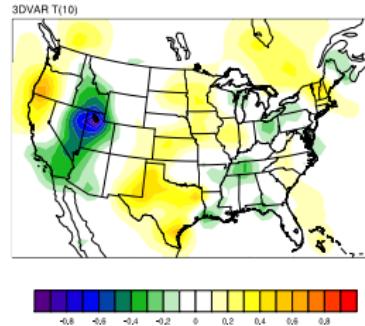
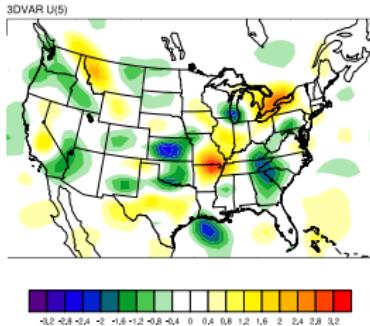
0:OBS_PARA: ps	13585
0:OBS_PARA: t	20639
0:OBS_PARA: q	19180
0:OBS_PARA: uv	28802
0:OBS_PARA: spd	80
0:OBS_PARA: sst	494
0:OBS_PARA: pw	766

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

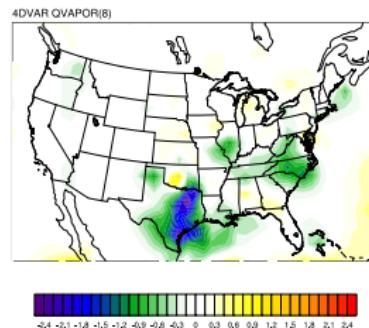
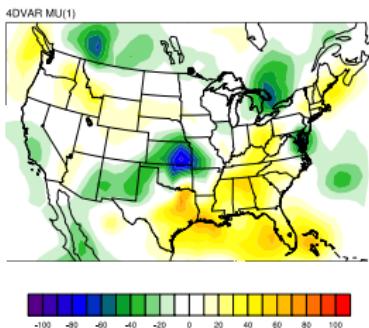
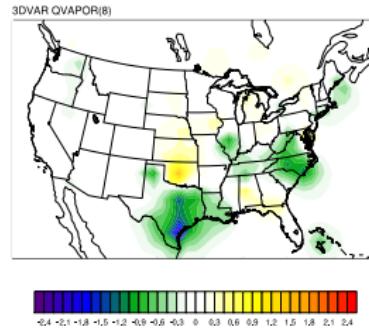
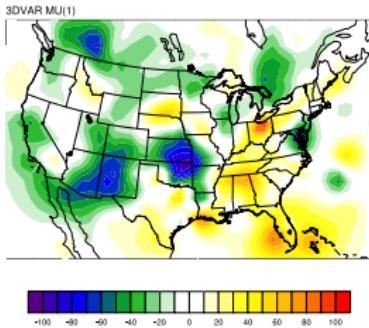
Cost functions and gradients



Sample increments comparison – U, T

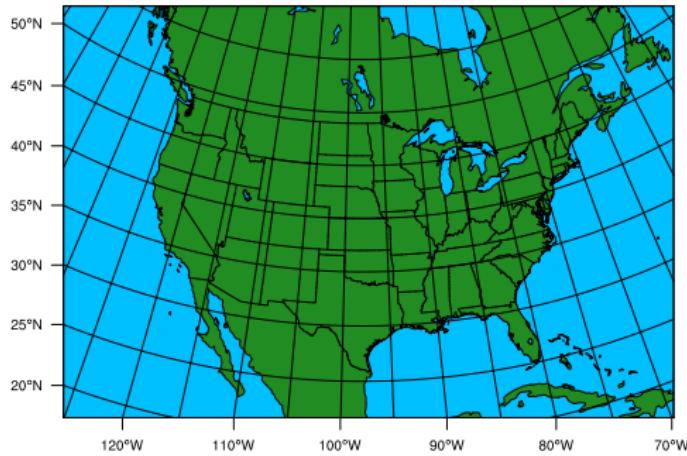


Sample increments comparison – MU, QVAPOR

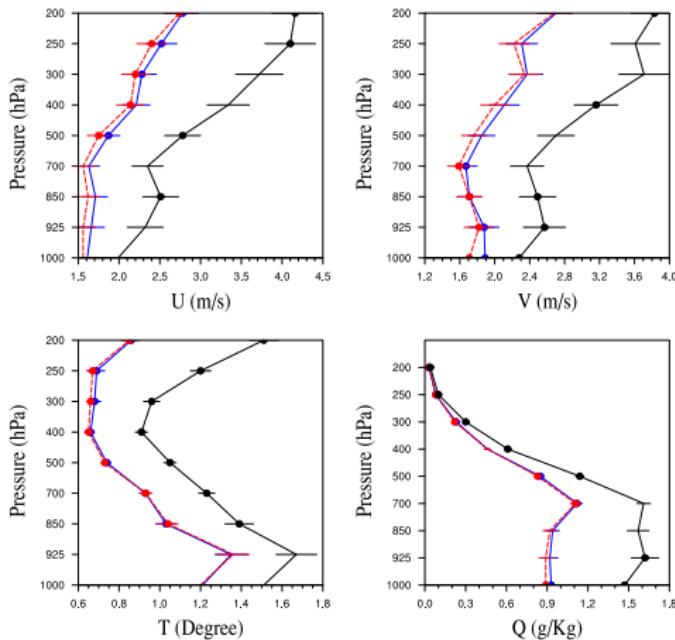


Domain

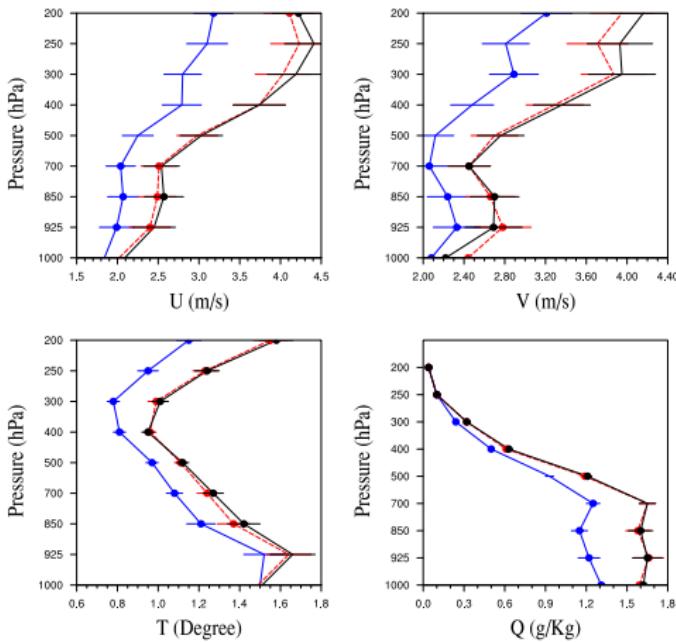
- Grids: 47x32x28L
- Resolution: 135km
- Period: 2007091000-2007091300 @0Z,6Z,12Z,18Z
- First guess is the 12h forecast from NCEP FNL
- 48h forecast from FG, 3DVAR and 4DVAR



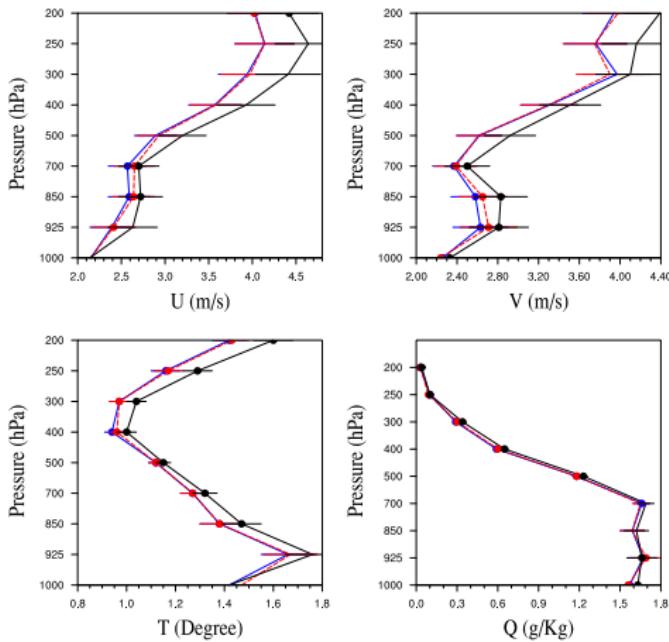
RMSE Verification—00h



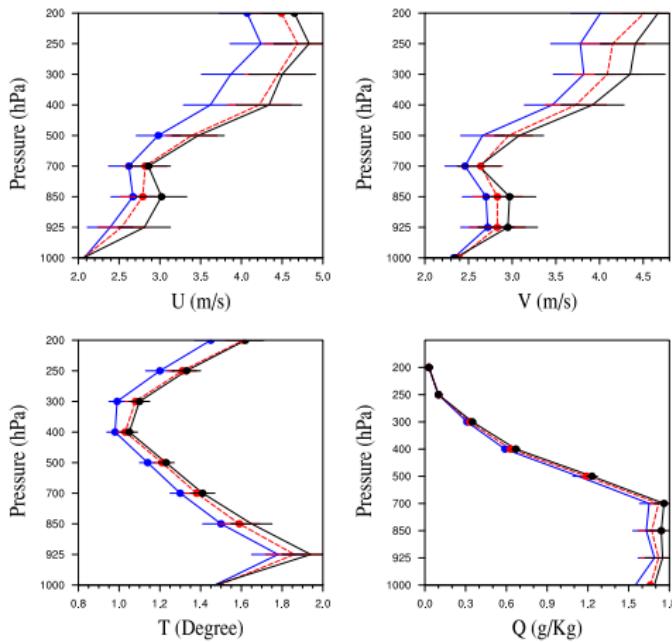
RMSE Verification—06h



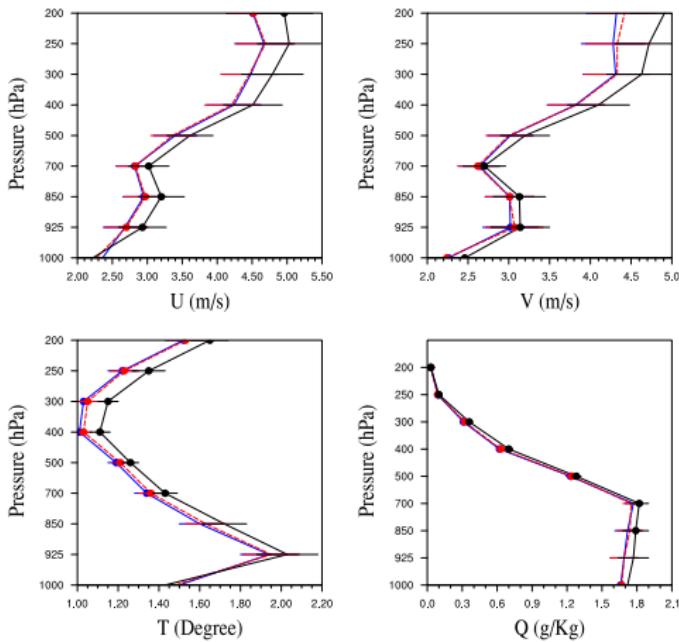
RMSE Verification—12h



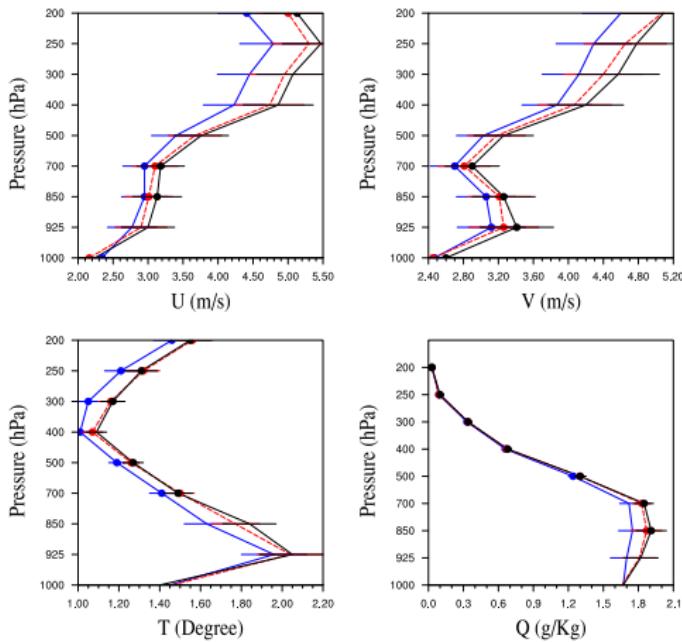
RMSE Verification—18h



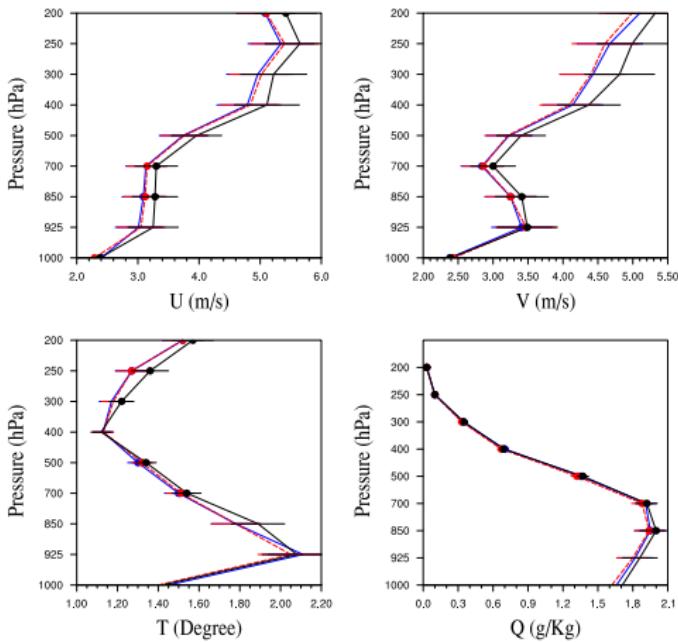
RMSE Verification—24h



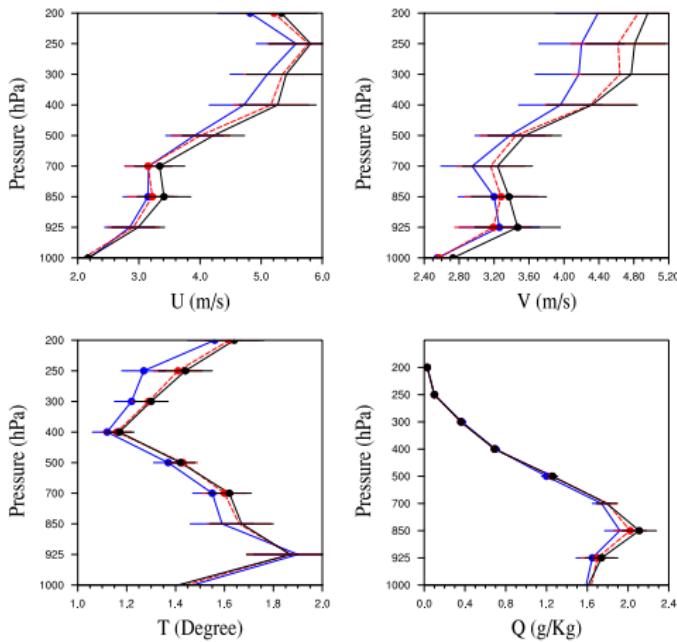
RMSE Verification—30h



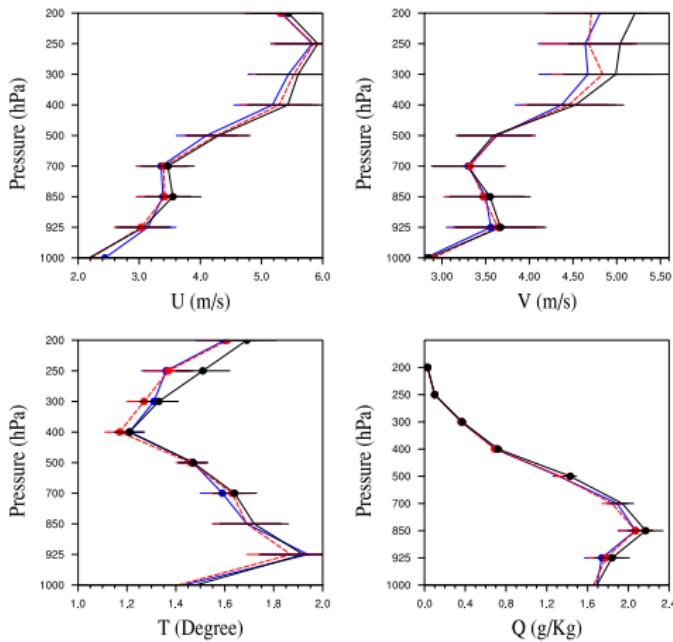
RMSE Verification—36h



RMSE Verification—42h



RMSE Verification—48h



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`



Summary

- The basic GSI/WRF 4DVAR system was developed with minimum codes modification.
- 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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- Multiple outer loops for 4DVAR.
- 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,
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