

Report on the development of GSI/WRF 4DVAR capability

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ACAPS Project Report

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- The Major development in GSI had finished, GSI codes had been coupled with the latest WRFPLUS
- Because the parallelization of the latest WRFPLUS is still on going, only 1 processor parallel run can be done 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 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
```

Modification of GSI

GSI Boulder repository revision 572, 2011-01-14

```
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/fill_mass_grid2.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/wrrwrfmassa.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/unfill_mass_grid2.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.

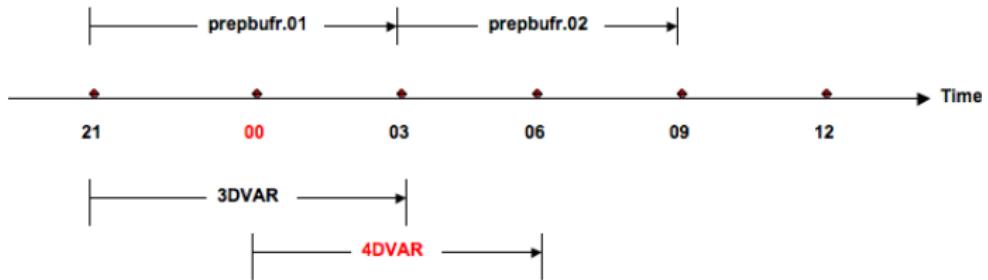
- Initial time: 2000_01_25_00 : 00 : 00
- Ending time: 2000_01_25_06 : 00 : 00
- Observation: 500 mb Temperature at **ending time**
 $O - B = -2.7K$
- To investigate the difference at **ending time** between the forecast from analysis and from background.

(Loading gsiwrf4dvar.mpeg)

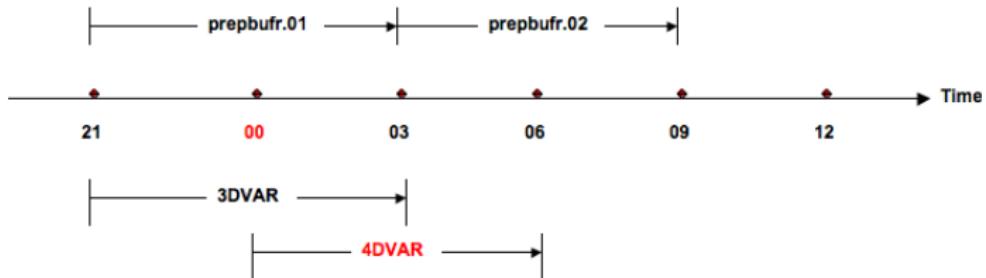
Forecasted 500mb T difference
(DA forecast - reference forecast)

- Initial perturbation is on the upstream of the obs.
- Evolved perturbation at 6h hit the obs. location
- Very obviously flow dependent characteristics

Tutorial case – Observation Usage



Tutorial case – Observation Usage



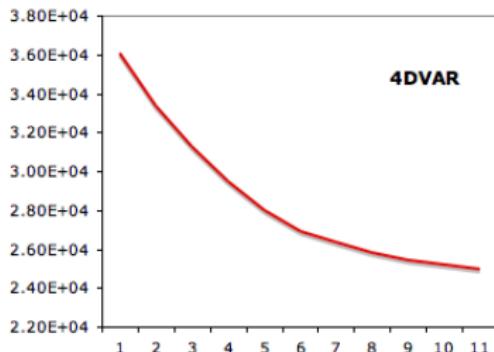
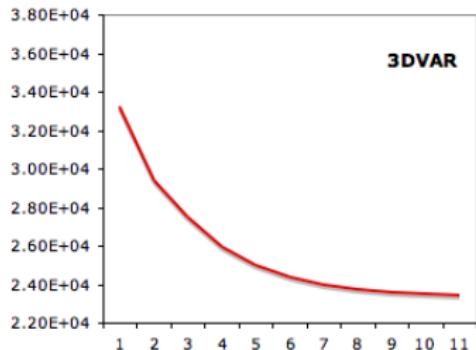
3DVAR

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

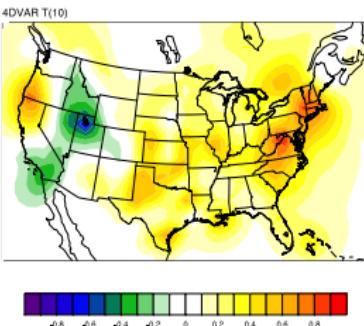
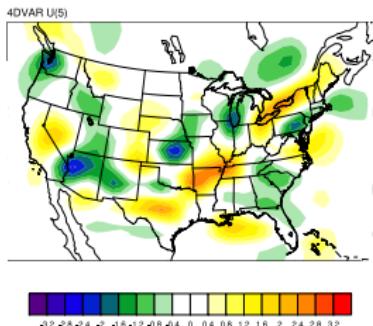
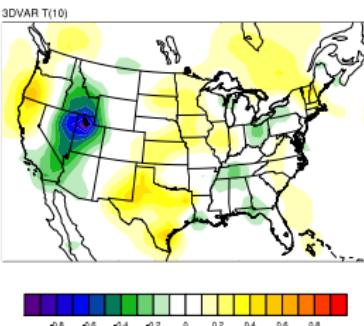
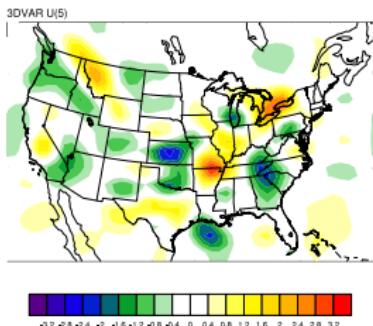
4DVAR

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
<hr/>	
0:OBS_PARA: ps	10
0:OBS_PARA: t	552
0:OBS_PARA: q	490
0:OBS_PARA: uv	568

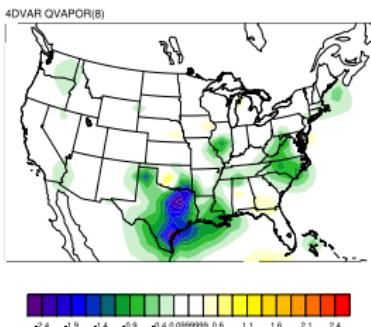
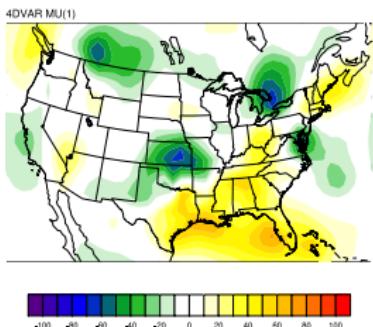
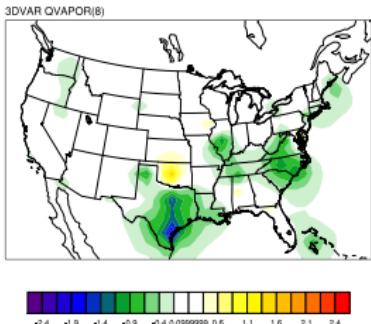
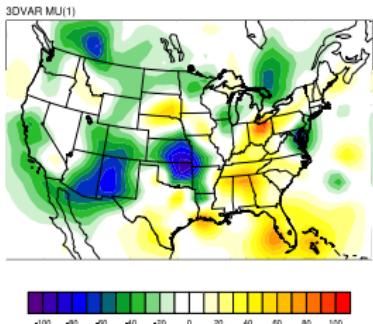
Cost function



Sample increments comparison – U, T



Sample increments comparison – MU, QVAPOR



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 GSI/WRF 4DVAR system was developed with minimum codes intervention.
- 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.

Under development

- Add simplified physics packages into WRFPLUS: surface drag, large scale condensation, a simplified cumulus scheme, as well as a radiation scheme.
- Parallelization of WRF adjoint codes.
- Polishing the boundary condition treatment during minimization.
- Finalize the adjoint check and gradient check for GSI/WRF 4DVAR.
- Conduct real data experiment to confirm the performance.

Thank You

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- To advance understanding of weather, climate, atmospheric composition and processes;
- To provide facility support to the wider community; and,
- To apply the results to benefit society.

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